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Adaptive Management: Harvesting the Benefits while Reducing the Risks for Ecosystem Restoration Projects

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Adaptive Management: Harvesting the Benefits While Reducing the Risks for Ecological Restoration Projects

by

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Dedication

I would like to dedicate this report to my parents, Richard and Nancy Jarrett, and in memory of my grandparents, Austin and Katherine Bateman, and Archie and Margie Jarrett. My parents instilled in their children a commitment to life-long learning and community service while constantly given their time, love, and support during my many years in school and professional practice. My grandparents made many sacrifices in an effort to give their children an opportunity to attend college and make it possible for their grandchildren and great-grand children to have greater opportunities than themselves. They also always reassured us that anything was possible through hard work and commitment.

This report is also dedicated to my boyfriend Andy Petruski for his love, support, and unwavering optimism and belief that I would and could meet the challenge of graduate school. Whether reading a draft to provide comments, running errands to give me a few more minutes to work on something, or providing a bit of comic relief, Andy's kind smile and gentle encouragement have been invaluable. I love you dearly.

I am eternally indebted to them all.

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Abstract

Adaptive Management: Harvesting the Benefits While Reducing the Risks for Ecological Restoration Projects

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Adaptive Management (AM) is an "approach to managing natural resources that emphasizes learning from the implementation of policies and strategies" (Allan & Curtis, 2005). The approach involves the monitoring and evaluation of hypotheses regarding system responses and/or the success of individual projects followed by integration of the findings into future efforts. It can be characterized as active (focused upon testing hypotheses) or passive (focused upon implementation). AM has been used by several federal and state agencies for the implementation of large-scale restoration efforts. This paper explores the use of AM in two large, regional water resources projects with state and federal agency involvement and significant ecological and economic resources at risk without intervention: the Sacramento-San Joaquin Bay Delta in California and the

Everglades Restoration in Florida. The paper explores potential avenues for further improvement of the AM efforts with an emphasis on: governance; establishment of networks to aid adaptive management, provisions for funding especially for active AM; cost-benefit analyses; and delegation of authority to allow for implementation of adaptive management.

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EXECUTIVE SUMMARY

Adaptive Management (AM) is an "approach to managing natural resources that emphasizes learning from the implementation of policies and strategies" (Allan & Curtis, 2005). The approach involves the monitoring and evaluation of hypotheses regarding system responses and/or the success of individual projects followed by integration of the findings into future efforts. It can be characterized as active (focused upon testing hypotheses) or passive (focused upon implementation). The use of adaptive management has become increasingly important to address and reverse the degradation of habitat due to increasing urbanization (Peterson, 2007). This approach may also benefit efforts to manage climate change. AM has been used by several federal and state agencies for the implementation of large-scale restoration efforts including the Sacramento-San Joaquin Bay Delta in California and the Everglades Restoration in Florida.

This professional report examines the concept of AM, its limitations and benefits, the guidance documents established by the U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service for AM, and the implementation of both the Sacramento-San Joaquin and Everglades efforts under AM. Following this examination, the author recommends some potential avenues for further improvement of the AM efforts with an emphasis on governance, establishment of networks to aid adaptive management, provisions for funding especially for active AM, cost-benefit analyses, and delegation of authority to allow for implementation of adaptive management.

CHAPTER 1 ADAPTIVE MANAGEMENT CONCEPT

History and Definition

Development of policies, particularly ones for renewable resource management require integration of science with decision making. The techniques utilized for evaluation of resource management vary but often rely upon laboratory or field experimentation and professional judgment. The specific learning mechanisms or methods of scientific inquiry that might be utilized for development of policies are summarized (Table 1).

The concept of adaptive management (AM) was originally established by C.S. Holling in 1978 and expanded by Walters in 1986 in response to the growing environmental movement in the United States (Lee, 1999). The interest in AM was also a response to "perceived limitations of traditional natural resources management approaches in the U.S. and around the world" (Panel on Adaptive Management for Resource Stewardship, 2004). Much of that effort was to address uncertainty in natural systems. The following quote describes the conundrum for decision makers:

> *Prediction of the future is possible only in systems that have stable parameters like celestial mechanics. The only reason why prediction is so successful in celestial mechanics is that the evolution of the solar system has ground to a halt what is essentially a dynamic equilibrium with stable parameters. Evolutionary systems, however, by their very nature have unstable parameters. They are disequilibrium systems and in such systems our power of prediction, though not zero, is very limited because of the unpredictability of the parameters themselves. If, of course, it were possible to predict the change in the parameters, then there would be other parameters which were unchanged, but the search for ultimately stable parameter in evolutionary systems is futile, for they probably do not exist* (Boulding, 1981, p. 44).

Table 1. Examples of Learning Modes, including AM

(Adapted from Lee, 1999)

Mode	Observational Method	Verification	Policy Planning	Basis of Usable Knowledge
Laboratory Experimentation	“Controlled observation to infer cause”	Replication and reliability established through experiments	“enabling prediction, design, control”	Theory
Adaptive Management	“Systematic monitoring to detect surprise”	“integrated assessment to build system knowledge”	inform model-building to structure discussions	Strong inference
Trial and Error	“Problem-oriented observation”	“extended to analogous instances”	To solve or mitigate particular issues	Empirical knowledge
Unmonitored Experience	“Casual observation”	“applied anecdotally”	Identifiable plausible solutions to intractable problems	Models of reality

(National Research Council: Panel on Adaptive Management for Resource Stewardship, 2004)

The functional definition proposed by the National Research Council has been widely adopted in the United States:

> *Adaptive Management (is a decision process that) promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events became better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process. Adaptive management also recognizes the importance of natural variability in contributing to ecological resilience and productivity. It is not a 'trial and error' process, but rather a means to more effective decisions and enhanced benefits. Its true measure is in how well it helps meet environmental, social, and economic goals, increases scientific knowledge, and reduces tensions among stakeholders.*

(U.S. Department of Interior Adaptive Management Working Group, 2009)

By its design, AM is intended to '…help managers learn about complex ecological systems by monitoring the results of a suite of management initiatives and implementing management interventions to achieve specific objectives (Gregory & Ohlson, 2006). Examples of adaptive management case studies include field test to assess seedling growth in response to alternative fertilization, fisheries restoration where a mix of standard and innovative restoration techniques are applied and evaluated to inform future restoration efforts, and assessing the potential effects of climate change based upon land use in an effort to isolate and address uncertainties and craft new policies (Gregory & Ohlson, 2006). As of the 1980's, approximately 100 riverine and other water-based adaptive management protocols were implemented (Gunderson & Light, 2006). As a result, the functional definition of adaptive management has evolved as well as recommendations for its implementation.

Benefits

Benefits of AM include its ability to advance decision-making by identifying and quantifying uncertainty as well as provide a framework for implementation and learning through monitoring and reevaluation (Huntsinger & Sorensen, 2010). Properly-designed AM can help to address scientific advances, environmental changes and variability, and shifts in social objectives and preference for long-term efforts (National Research Council: Panel on Adaptive Management for Resource Stewardship, 2004). By aggressively using management intervention as a tool, adaptive management can strategically probe the functioning of an ecosystem and the success of a habitat restoration effort (Resilience Alliance, 2010). Uncertainties and hypotheses developed during the design are the basis for future evaluations and can aid other future restoration efforts (Resilience Alliance, 2010).

Limitations

AM also has its limitations. AM is intended to address very specific situations when a majority of the project effects are generally understood but some effects may not be understood and data cannot be collected in a sufficiently short timeframe to improve that understanding (Huntsinger & Sorensen, 2010). This conflict, sometimes referred to as a conflict in space and time scale, is best managed by development of integrative models that allow comparison of policy decisions or direct comparison of performance in the field (through planned experimental comparisons) (Walters C. J., 2007). In Dr. Walters's judgment, integrative models (sometimes called conceptual or system models) and other more experimental methods are only appropriate if these approaches allow improved management of the system. He further argues that if historical data is sufficient to manage uncertainty without additional tools that modeling and more experimental methods are not necessary.

Other issues with AM include incorrect information or poor public involvement efforts. Incorrect understandings and information can result in implementation of projects or policies which have severe, negative consequences (Resilience Alliance, 2010). Poorly explained AM can also confuse stakeholders and result in ambiguous goals and poor management decisions (National Research Council: Panel on Adaptive Management for Resource Stewardship, 2004).

Passive and Active AM

AM approaches are typically divided into passive and active which reflect the decision-making process for the effort, including active analysis of multiple hypotheses during the program[1]. Passive AM is defined as the selection of one preferred course of action, followed by monitoring during implementation, which, ultimately results in adjustments to future work approaches based upon the performance of the preferred course of action (National Research Council: Panel on Adaptive Management for Resource Stewardship, 2004). In active AM, several alternatives are identified and implemented as results are obtained and compared to address multiple hypotheses

[1] Some authors identify a third form of AM: evolutionary. Under their reasoning, evolutionary AM is undirected learning based upon random experience or "trial and error learning" (Allan & Curtis, 2005). This definition precedes the current practice of AM and therefore is not presented in this paper

(National Research Council: Panel on Adaptive Management for Resource Stewardship, 2004). The learning gained by active AM is then used to refine future efforts.

Another way to characterize passive AM is that "…managers typically use historical data, from the specific area under consideration or from areas considered to be ecologically comparable, to develop a 'best guess' hypothesis and implement a preferred course of action" (Gregory & Ohlson, 2006). Effective passive AM typically involves:

- *An active culture of reflection comprising effective evaluation, rewards for thinking and reflection, and appropriate communication for all project participants; and*
- *Provision of mechanisms for incorporating learning into planning and management.*

(Allan & Curtis, 2005)

In contrast, active AM seeks to "…define competing hypotheses about the impact of management activities on ecosystem functions, and, in turn design management experiments to test them." (Gregory & Ohlson, 2006) Active AM incorporates the above features of passive AM as well as:

- *Management activities are specifically designed to test hypotheses through ecosystem scale holistic experiments;*
- *Complexity is embraced; provision of mechanisms for multidisciplinary and multi-stakeholder involvement; and*
- *There is a strong emphasis on social learning.*

(Allan & Curtis, 2005)

The resulting analytical requirements of the active approach are slightly higher than a passive approach and require experimental design and statistical analyses. This approach may also yield information that is more valuable for similar future projects. It is also important to note that active adaptive management involves development of a range of competing, alternative system models rather than one model which is a basis for the decision making (National Research Council: Panel on Adaptive Management for Resource Stewardship, 2004).

When defining AM, it also important to recognize that the practice of AM is evolving. This change includes prevalence of AM's use, scientific methods available to support AM, and structure of feedback mechanisms and governance. For example, between 1979 and 1999, one researcher was involved in the an evaluation of 20 riparian restoration programs, only 7 involved experimental management including active monitoring and modeling (Gunderson & Light, 2006). Since 1990, this trend has changed, and more holistic approaches to water resources, including integrated water resources management (IWRM) and AM, have become increasingly more common (Pahl-Wostl, 2007). This trend may be symptomatic of new technology and active AM's ability to provide greater benefits in the planning stages of a project rather than during implementation (Gregory & Ohlson, 2006). The integration of new technology, such as information systems and improved models, and increased understanding of AM is expected to increasingly lend itself to geographically larger, more complex projects rather than its limited initial successes in only small-scale projects. The following chapter describes lessons learned from earlier implementation of AM.

CHAPTER 2 COMMON ISSUES AND LESSONS LEARNED

The literature recognizes the challenges of AM as it applies to stakeholder involvement, decision-making and successful implementation. The following sections address common issues with AM and the key strategies for successful programs in response to those common issues.

Recognizing And Embracing Uncertainty

Uncertainty can vary substantially by individual policy issues or project and can include uncertainties within an ecological system, individual decision-making tools, and the governance structure of a program. The best recognized form of uncertainty is a lack of knowledge because of the limited availability and variability of data (Pahl-Wostl, 2007).

Other forms of uncertainty involve the understanding of the system itself, including historical trends, system elements, and interactions. Within ecological systems, scale and complexity of system interactions directly affect uncertainty. A larger study area or greater spatial complexity and temporal limits can be extremely challenging (Gregory & Ohlson, 2006). Some other sources of uncertainty include:

- Identifying and understanding physical, chemical, and biological linkages in models, especially over large geographic areas or long-time periods using short intervals which require more accurate and/or complex models

- Recognizing the cumulative and possibly non-linear compounding of model errors when analyzing population dynamics

- Characterizing ecological processes is extremely difficult when the process is relatively new to science and not well-understood
- Validating current models may be limited by a lack of historic data

(Walters C. , 1997)

Another aspect of uncertainty is generated by the problem-solving process itself. Participants in an AM process may each have unique perspective on both the ecological processes, acceptable approaches and outcomes, and appropriate processes to achieve an outcome (Pahl-Wostl, 2007). This simultaneous presence of multiple frames of reference when seeking to understand a phenomenon is called "ambiguity." In addition to ambiguity, the ability of a society to agree to a suitable political and institutional environment to support AM (context), establish effective policy programs to analyze and frame issues amongst interdependent institutions (network), and policies to shape individual behavior and collective negotiations (social interaction or game) are all sources of uncertainty (Pahl-Wostl, 2007).

The context of a program over a long period will be altered not only by elections of public officials but also changes in the needs and expectations of stakeholders – both locally and nationally. Networks may evolve as a result of learning from the project, changes in their individual missions, and in response to outside pressures. Within these networks, individual parties may select specific strategies that also affect decision-making and the network. Decision-makers and institutions must be aware of these potential uncertainties and establish protocols to help avoid the negative effects but also benefit from stakeholder input and flexibility in decision-making which benefits program objectives.

In order to benefit from AM's ability to advance scientific understanding and decision-making, participants in AM must embrace but also remain vigilant regarding their understanding and interpretation of uncertainty, in each of its many forms (Gregory & Ohlson, 2006).

Articulating Clear Goals Based Upon Science

To be successful, adaptive management requires a clear articulation of the desired outcomes or management goals/objectives based upon a scientific process which recognizes uncertainty (Marmorek, 2004). Elements of successful AM efforts merge both science and public involvement to establish and communicate clear goals (Resilience Alliance, 2010). These programs typically encompass the following principles.

1. management is tied to appropriate temporal and spatial scales
2. the process retains a focus on statistical power and controls
3. use of computer models to build understanding and consensus
4. use ecological consensus[2] to evaluate strategic alternatives

[2] Ecological consensus is a consensus established by the scientific community relating specific forces or parameters to ecosystem functions (Hooper, 2005). Forces may include biotic and abiotic controls, and factors might include biodiversity. The anticipated changes in ecosystem functioning are then utilized to manage resources. The practice of ecological consensus is now being expanded to also consider the social and economic constraints of potential management practices.

5. communicate alternatives to political decision-makers to select a preferred alternative

For example, the State of Texas passed legislation[3] mandating that Texas Commission on Environmental Quality (TCEQ) adopt environmental flow standards for the river basin and bay systems in the state (Texas Commission on Environmental Quality, 2010). The purpose of the legislation was to establish flow recommendations that would preserve the biotic environment of rivers and estuaries. To establish a scientific basis or ecological consensus for the effort, the legislation established Basin and Bay Expert Science Teams (BBEST) which would evaluate riverine and estuarine needs for specific basins. The BBEST would then utilize modeling, existing literature, and professional judgment to establish a basin-specific consensus and evaluate various alternatives. Recommendations for each basin would then be communicated to and vetted with the public. Some of the basins have already evaluated their options and established specific recommendations. For example, the Trinity River BBEST has recommended a minimum instream flow of 3 meters per second [4], for a period exceeding 10 days while temperatures range from 10 to 17 °C, (Environmental Institute of Houston, University of Houston Clear Lake, 2009).

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[3] The legislation included the House Bill 3 and Senate Bill 3, of Texas' 80th Legislature passed in 2007,
[4] This value represents the average magnitude of spring water rise in the river over average midwinter flow.

Engaging Committed Decision-Makers

A degree of engagement by decision makers also substantially affects the success of an AM program. Decision makers are responsible for not only serving as an additional level of scrutiny for scientists but also as true policy decision makers (Walters C. J., 2007). To be successful, decision makers must not only abandon intuitive simplistic arguments (e.g. species will benefit because of one element) but also invest intellectual capital in the process. The decision-makers must be prepared to closely scrutinize different or ambiguous predictions when the scientific community examines causal pathways and mechanisms to develop initial recommendations (Walters C. J., 2007). They must clearly accept the responsibility for risk management with the support of the project team.

Decision makers are also most successful when they actively engage in the planning and implementation efforts. Examples of this leadership include:

- developing a board overview of decision-making and implementation processes, including technical and administrative details and staff
- focusing upon organization, including tasks and schedule
- rejecting inaction or unnecessary delays
- committed participation for long periods of time

(Walters C. J., 2007)

Providing Adequate Funding for Monitoring Programs

Lack of adequate monitoring data and historical reference information has become “a universal complaint in natural resources management, independent of experimental management initiatives” (Walters C. J., 2007). Without adequate funding, programs can not engage in the replication of modeling analyses and repetitive monitoring. Programs cannot also properly response to uncertainty, including political uncertainty, without adequate funding (Pahl-Wostl, 2007). The program may also be unable to recruit and retain trained staff and maintain its focus on learning. As a result, the ability of the program to understand a complex, open ecological system is severely compromised (Walters C. J., 2007).

Avoiding the “Management Trap”

Gunderson and Holling established the concept of a “management trap”, a “social trap where a system configuration or regime persists over time in spite of being subjected to a wide range of shocks and perturbations” (Gunderson, Light, & and Holling, 1995). Case studies of AM efforts in both Australia and the Pacific Northwest also argue that institutional management and societal norms reinforce the “management trap” and especially compromise regional-scale AM (Allan & Curtis, 2005).

In a “management trap”, managers are not allowed or encouraged to employ innovation through experimentation and alternatives. As a result, managers are so highly constrained that they cannot capitalize on new information and implement effective AM. Major modifications are considered failures rather than learning experiences. As a result, the status quo is reinforced rather than learning and implementation. The repeated perception of failure also results in a lack of trust between management and stakeholders. The lack of trust disrupts public involvement and further compromises feedback mechanisms.

Establishing Realistic Cost-Benefit Analysis Protocols

AM programs need to be designed with costs, benefits, and risks defined as clearly as possible (Gregory & Ohlson, 2006). The benefits and costs should be clearly identified and considered in light of evaluating multiple hypotheses when implementing active AM. Furthermore, experts recommend that AM clearly identify potential opportunity costs, the risks of ending projects early, the magnitude of the effect, and trade-off between multiple objectives. Another critical aspect of a successful effort includes recognition of high monitoring costs necessary to achieve the benefits of AM (Walters C. , 1997). In some instances, the benefit-cost analyses do not consider intergenerational trade-offs where temporary inconvenience transitions into long-term benefit. The following sections address the regulatory context and evolving guidance regarding AM implementation.

CHAPTER 3 REGULATORY CONTEXT AND EVOLVING GUIDANCE

Several agencies are developing criteria to help to improve their approach to AM. These policies have also been adopted to address climate change and other variable conditions. The U.S. Army Corps of Engineers, and more specifically its Civil Works projects, particularly water resources projects involving habitat restoration, are increasingly relying upon adaptive management. The USACE Civil Works program conducts a variety of studies to achieve several authorized purposes, including flood control, navigation, ecosystem restoration, as well as pre-construction engineering and design, construction, and operations and maintenance (U.S. Army Corps of Engineers, 2009).

U.S. Army Corps of Engineers

Civil Works projects are regulated by the internal processes of the USACE as well as the National Environmental Policy Act of 1969 as amended (NEPA), which requires evaluation of project effects when federal permits or funds are granted or federal policies are adopted or modified. The Civil Works program is grounded in a project delivery philosophy that complements NEPA. The major phases of the effort are illustrated on the left and the specific work objectives identified on the right (Figure 1).

Both the Civil Works process and NEPA require consideration of future conditions without the project, project alternatives, and the effects on the human and natural environment of each of these alternatives (Council on Environmental Quality, 2002).

Identify Problem

- Stakeholders define the problem and opportunities

Inventory and Forecast Conditions

- Collect physical, economic, and environmental data
- Conduct scoping for NEPA document
- Define the future without-project condition is defined

Formulate Alternative Plans

- Consider all viable alternatives, including structural and non-structural alternatives and a without project or “no action” alternative
- Address completeness, effectiveness, efficiency, and acceptability

Evaluate Alternative Plans

- Estimate costs and benefits including environmental impacts of each plan for the accounts
- Follow planning approach or obtain waiver

Compare Alternative Plans

- Compare plans environmentally, economically, socially, etc.
- Evaluate monetary and non-monetary benefits and costs
- Rank alternatives including no action

Select Recommended Plan

- Identify the National Economic Plan (NEP) or Locally Preferred Plan (LPP)
- For ecosystem restoration, identify the National Ecosystem Restoration (NER) Plan

Figure 1. USACE Project Delivery Process

The Civil Works process requires an understanding of the monetary and nonmonetary costs and benefits of each project alternative (U.S. Army Corps of Engineers, 2000) as well as compliance with the Council on Environmental Quality (CEQ)'s guidelines for NEPA documents. The alternatives identified in the Civil Works process include the alternative with the highest national benefits or National Economic Development (NED) (which can include but are not limited to navigation and flood control), the Locally Preferred Plan (LPP) which represents the non-federal sponsor's preferred alternative, and the National Ecological Restoration (NER) which represents the highest ecosystem restoration benefits. Ultimately the process concludes with adoption of a preferred alternative by the agency. In order to select a preferred alternative, the USACE Civil Works process encourages greater reliance on a more passive adaptive management approach by its requirement to select a preferred alternative and evaluate specific alternatives from a cost-benefit perspective. It is also significant that the individual projects under the Civil Works program compete for funding on the basis of the benefit-cost ratio for individual projects and are subject to competing interests between USACE districts, agencies, and elected officials

NEPA, and the CEQ, allows for use of AM; however, guidance for AM is limited. In 2002, the CEQ recommended some specific considerations during implementation of AM:

- *Ability to clearly define the intended outcome;*
- *Magnitude of the potential environmental impacts of the proposed action;*
- *Ability to measure outcome attainment (e.g., impact; thresholds/performance measures);*
- *Monitoring requirements;*

- *Cost of implementing post-decision monitoring and corrective actions;*
- *Commitment of the agency to fund monitoring and follow through on the adaptive measures;*
- *Need for management or response flexibility; and*
- *Acceptability by and commitment of regulators and stakeholders to the adaptive management approach.* (Council on Environmental Quality, 2002)

The National Research Council (NRC) conducted a study of the USACE's implementation of AM and recommended several process improvements which have not yet been adopted (National Research Council: Panel on Adaptive Management for Resource Stewardship, 2004). The recommendations included increased funding, funding policies to promote adaptive management, and requirements for increased agency interaction. The following quote summarizes additional specific recommendations from that panel:

- *Post-construction evaluations should be a standard for adaptive management of Corps (USACE) projects and systems.*
- *Stakeholder collaboration should be an integral component of the adaptive management of Corps projects and systems.*
- *Independent experts should be periodically enlisted to provide advice on Corps adaptive management initiatives.*

(National Research Council: Panel on Adaptive Management for Resource Stewardship, 2004)

The USACE continues to implement and refine its approach to AM. On December 9, 2009, the CEQ requested a reevaluation of the USACE's planning and principles guidance for water resources projects, referred to as the Principles and Guidelines (P&G), by the National Academies of Science (NAS) (Council on Environmental Quality, 2010). The resulting guidance, by presidential mandate, will be adopted for all future federal water resources projects. Expected in November 2010, a review of the web site indicates the study is still in progress (National Academies of Science, 2010).

Department of Interior, including the U.S. Fish and Wildlife Service

Within the Department of Interior (DOI), interior manuals establish policies to prevent "trial and error" approaches to adaptive management (U.S. Department of Interior, 2008). This can be significant for water resources projects because the U.S. Fish and Wildlife Service (USFWS), a division of the DOI, has jurisdictional authority over the Endangered Species Act (ESA). Compliance with ESA is a requirement under the Civil Works requirements as other construction and maintenance activities within the United States. A recent guidance document produced by the USFWS adopted the NRC's operational definition of adaptive management, defines when adaptive management is appropriate, and the process for its use (U.S. Department of Interior Adaptive Management Working Group, 2009). The recommended approach includes consideration of the temporal sequence of decisions in relationship to the state of the environment, particularly habitat for endangered or threatened species. The DOI also encourages adaptive management when uncertainty can be expressed as a set of testable models whether qualitative and conceptual or quantitative and detailed. The approach also relies upon monitoring to reduce risk and uncertainty. The DOI does acknowledge that a supplemental NEPA document would be required for changes due to an adaptive management approach not specified in the original plan; if impacts might be significant, a supplemental EIS would be required. The guidance also describes provisions for the use of adaptive management which is well defined in the use of Habitat Conservation Plans to obtain compliance with the ESA. The DOI program recommends consideration of the following.

- *Engaging the relevant stakeholders in the decision-making process*
- *Identifying the problem to be addressed*
- *Specifying objectives and tradeoffs that capture the value of stakeholders*
- *Identifying the range of decision alternatives from which actions are to be selected*
- *Specifying assumptions about resource structures and functions*
- *Projecting the consequences of alternative actions*
- *Identifying key uncertainties*
- *Measuring risk tolerance for potential consequences of decisions*
- *Accounting for future impacts of present decisions*
- *Accounting for legal guidance and constraints*

(U.S. Department of Interior Adaptive Management Working Group, 2009)

The evolving practice of adaptive management also includes recommendations for monitoring. “Monitoring” is the systematic and usually repetitive collection of information, typically used to track the status of a variable or systems (USGS, USFWS, and CA Department of Fish and Game, 2004). Two types of monitoring have also been identified:

- *Implementation (compliance) monitoring* tracks the status of plan implementation, ensuring that planned actions are executed.
- *Effectiveness monitoring* evaluates the success of the plan in meeting its stated biological objectives.

A subset of monitoring-targeted studies-can be used to increase the effectiveness of monitoring and management. It also improves knowledge about the ecological system and aid in the resolution of or reduction of risk associated with critical uncertainties. The recommended approach to incorporation of adaptive management and monitoring with regard to the ESA is illustrated below (Figure 2).

Prevention of misunderstanding with stakeholders to enable consensus building is a common concern. The ability to define decision-making points as well as identify and explain or limit uncertainty through modeling are cited as key considerations from inception through implementation. Potential conflicts between the requirement to select a preferred alternative in compliance with NEPA, the Civil Works process, and ESA compliance and the benefits of an active adaptive management approach further complicate the decision-making process and implementation.

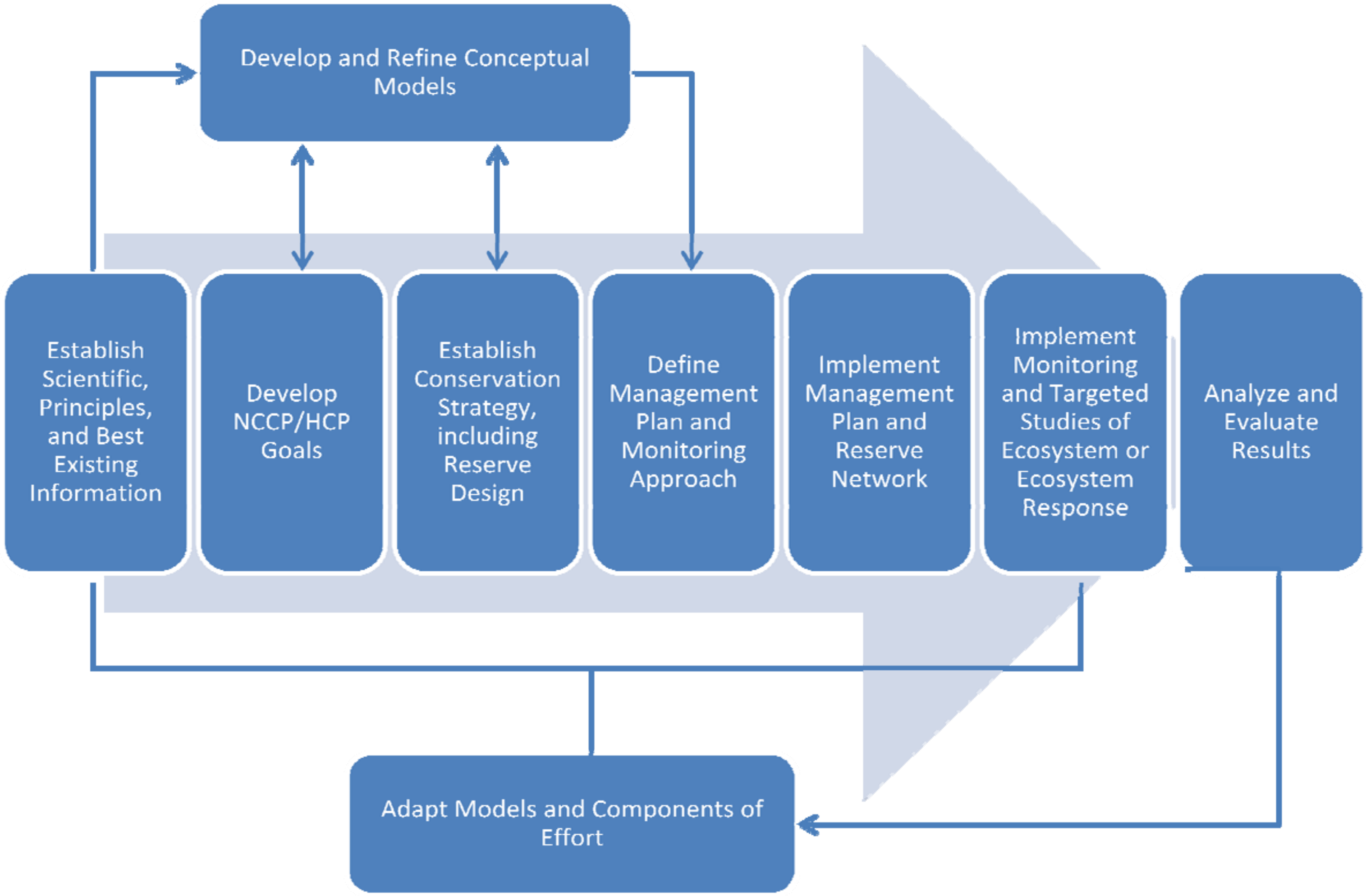

Figure 2. NCCP/HCP Adaptive Management Feedback Loop

(U.S. Department of Interior Adaptive Management Working Group, 2009)

CHAPTER 4 CASE STUDIES

Following completion of initial research, the author identified two existing restoration projects for further study: the Delta Regional Ecosystem Restoration Plan, California and the South Florida Ecosystem Restoration, FL. The programs were selected because they were well-established to support an evaluation and represented large-scale projects. The projects also exhibited the similar attributes of great interest in the practice of AM:

- large, regional scale water resource projects covering large hydrologic systems, spanning multiple water bodies
- involvement of local, regional, state and federal agencies as well as private and nonprofit parties
- sensitive biotic resources that are either endangered and threatened under the ESA
- priority resources of nationwide significance, such a significant populations, agricultural production of national significance
- the presence of multiple ecological services provided by these resources which are at risk of being degraded or lost if measures that counteract or compensate for human impacts are not successfully instituted

The author reviewed existing literature on both projects, including professional journals, critiques of the programs by other agencies, including the NAS, and conducted research on existing editorials and public opinion for both projects. Both efforts have been extensively reviewed on both the national and local level for effectiveness. The author also contacted the following agencies in late September through November 2010 to obtain interviews with staff: State of California, Delta Council, two chapters of the Sierra Club (South Florida and Central California), U.S. Army Corps of Engineers Jacksonville District, U.S. Fish and Wildlife Service, Natural Resources Defense Council, South Florida Water Management District (SFWMD), and the California Legislative Analyst's Office. The results of organizations willing to participate in the interviews are provided in the case studies as well. The following sections summarize the results of that research.

Delta Regional Ecosystem Restoration Implementation Plan

BACKGROUND

The San Francisco Bay/San Joaquin Delta Estuary (Bay-Delta), located at the confluence of the Sacramento and San Joaquin Rivers, is the largest estuary on the western coast of the United States (CALFED Bay-Delta Program 1999). Comprised of 75,000 acres, the Bay is located in central California adjacent to San Francisco (Figure 3) (CALFED Bay-Delta Program, 1999). The Bay-Delta is fed by the Sacramento (flowing south) and the San Joaquin Rivers (flowing north) (State of California, 2006) (Figure 4). The River System is on the verge of ecological collapse with severe constraints on water supply and limited flood protection (American Rivers, 2010). As a result, the availability of the water supply for 23 million people is questionable. The state capital is at high risk for flooding, and the river's ability to support habitat for federally and state-protected and other species is also compromised. This situation has resulted in Sacramento-San

Joaquin's inclusion on the America's Most Endangered Rivers™ list, produced by American Rivers, for the second year in a row. This characterization results from a combination of factors including urbanization, agricultural development, and alteration of the river itself.

The Bay-Delta is characterized by peat and peaty alluvium deposited by streams from the Sierra Nevada, Coast Ranges, and southern Cascade Range when they enter the delta and San Francisco Bay (U.S. Geologic Service, 2000) (Figure 5). The soils and climate were extremely well-suited to agricultural development. Although the "Mediterranean" climate of the Bay-Delta, including seasonal summer droughts and heavy rains in winter, does result in extremely variable water supplies (U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency, 1989). In the late-1800s, significant agricultural development in the Delta coincided with levee building to control flooding and extensive draining, clearing and tiling of wetlands. In 1999, the Basin contained 641,000 acres of farmland and 85 percent of the state's irrigated farmland (CALFED Bay-Delta Program, 1999). The Basin also contributed 95% of California's agricultural economy.

Approximately 10,000 acres have been set aside for urbanization by local land use plans. Another estimated 50,000 acres of farmlands will be converted to dedicated ecological preserves. The potential for continued population growth not only limits potential ecosystem restoration efforts and demands additional water supplies. The expected increase of the state's population from 34 million in 2000 to 59 million in 2040

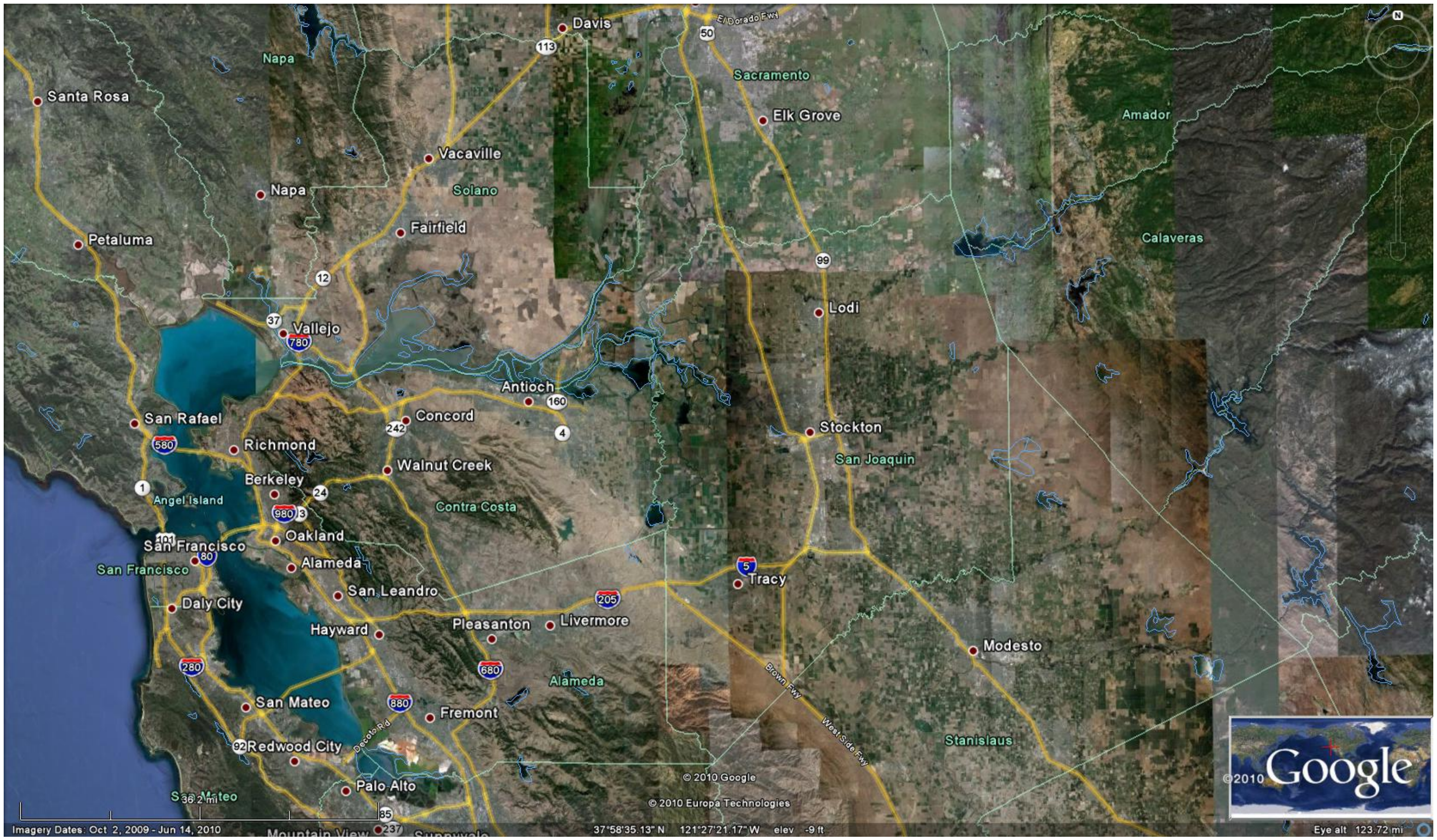

Figure 3. Illustration of the San Francisco-San Joaquin Estuary

Source: Google Earth, 2010

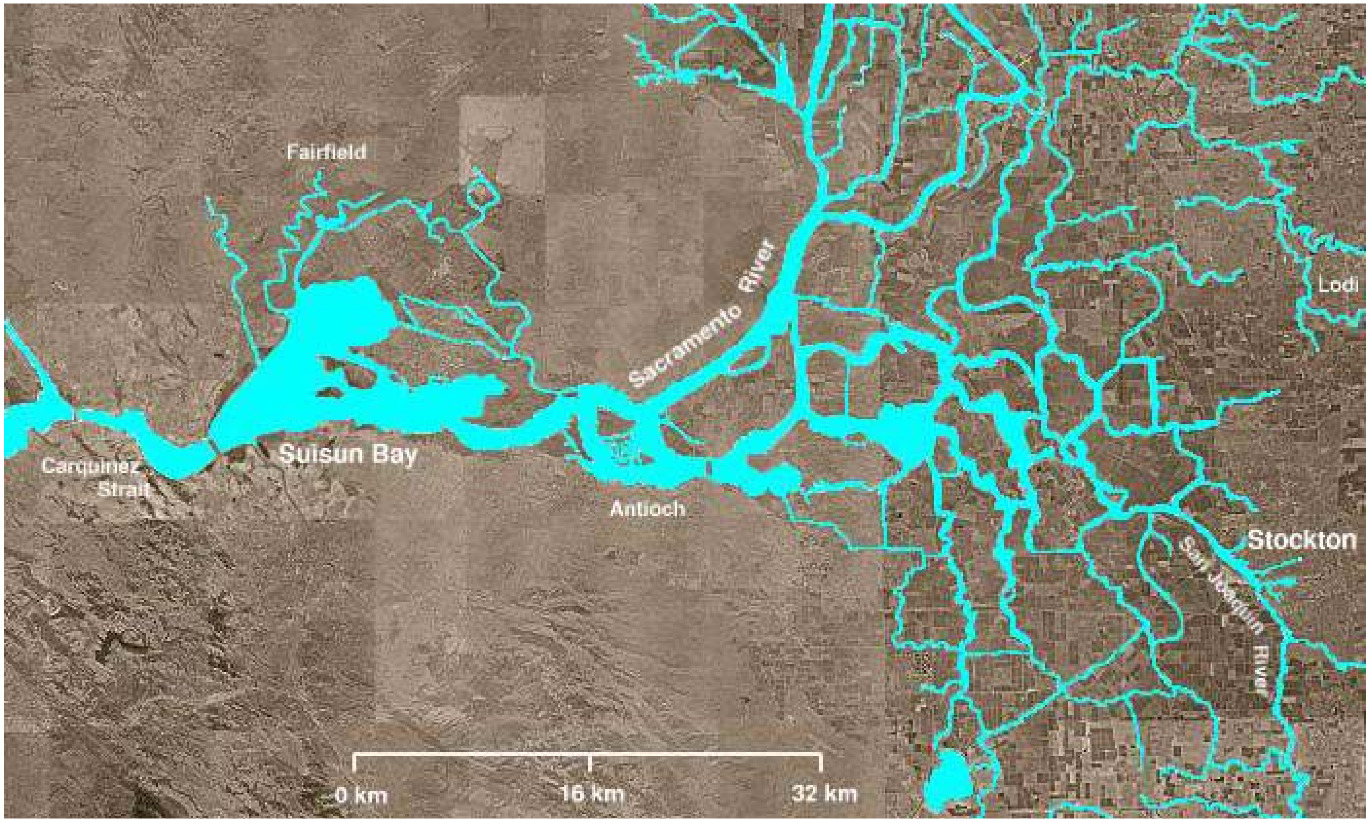

Figure 4. Illustration of the Major Rivers of the Sacramento-San Joaquin River Delta

Source: Matthew Trump, 2004[5]

[5] Permission is granted to copy, distribute and/or modify this document under the terms of the **GNU Free Documentation License**, Version 1.2 or any later version published by the Free Software Foundation; with no Invariant Sections, no Front-Cover Texts, and no Back-Cover Texts. A copy of the

Figure 5. Representative Photo of the Bay Delta

Source: Heikkila, 2009

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will continue to challenge the basin and affect water supplies (California Bay Delta Program, 2000). An estimated 20 to 70 percent of the natural flow in the basin system has been reappropriated.

Prior to the agricultural development, the Bay-Delta was characterized by dense vegetation (Warner, 1984). In 1848, the Sacramento River contained an estimated 800,000 acres of riparian forests; no estimates are available for the San Joaquin Valley from 1848. Studies suggest that the riparian vegetation prior to pre-settlement consisted of 921,000 acres.

Marsh vegetation (primarily *Scirpus spp.* and *Typha spp.)* typically included extensive perennial grassland (*Stipa spp.).* Uplands were characterized by scattered valley oak (*Quercus lobata*) woodlands, and the southern edge of the valley was characterized by large areas of salt brush desert (*Atriplex spp.).* Riparian forests included structurally and floristically complex communities including dense layers of undergrowth and vines. These included:

- Upper canopy consisting of Fremont cottonwood (*Populus fremntii*), California sycamore (*Platanus racemosa*), willow (*Salix spp*.), and valley oak
- Intermediate canopy consisting of box elder (*Acer negundo subsp. californicum*), Oregon ash (*Fraxinus latifolia*), and various species of willows
- Vines (lianas) including wild grape (*Vitis californica*), poison oak (*Rhus diversiloba*), Dutchman's pipe vine (*Aristolochia californica*), and wild climatic (*Clematis spp.*)
- Underground including mugwort (*Artemisia douglasiana*), mulefat (*Baccharis viminea*), wild rose (*Rosa californica*), and blackberry (*Rubus spp.*)

Since the agricultural development, riparian forests and other vegetation have been significantly reduced. In 1979, the California State University estimated that only 102,000 acres of riparian forests remained with 49,000 of that degraded and 53,000 of remaining mature riparian habitat. Small pockets of grassland and ruderal[6] habitats remain with a limited number of vernal pools in the fringes of the delta that support several special-status species (CALFED Bay-Delta Program, 1999). These include tadpole shrimp (*Lepidurus packardi*) and fairly shrimp (*Branchinecta lynchi*).

Fish species have also dramatically declined. Since 1967, biologists have carefully monitored fish populations with the river (NBC News, 2008). In 2008, California Department of Fish and Game biologists recognized that increasing downward trends in fish populations (first recognized in 2000) were accelerating. The Delta Smelt (*Hypomesus transpacificus*), considered a key indicator species of the delta's health, was listed as threatened under the Endangered Species Act in 1993, and by 2008, was under consideration as a candidate species for endangered status. Other species listed for the ESA include Chinook salmon (*Oncorhynchus* sp.), steelhead (*Oncorhynchus mykiss)*, and Sacramento splittail (*Pogonichthys macrolepidotus*).

That same year, a Biological Opinion (BO) indicated that California's water program was likely to jeopardize the continued existence of the Delta Smelt (Regional Director, U.S. Fish and Wildlife Service, Region 8, 2008). Other species evaluated in that same BO were not considered to be put in jeopardy. Key issues in the Delta Smelt

[6] Habitat characterized by waste ground (Farlex, 2010).

evaluation included entrainment due to pumping, the effects of invasive species, hydrodynamic effects, and effects of degraded water quality.

Other challenges affecting a wide range of fish species include declining zooplankton and phytoplankton within the Basin, especially in the estuary (Carpenter, 2002). Decreases in plankton have been associated with the effects of heavy metals, herbicides, pesticides, high levels of suspended sediments, and other water pollutants (CALFED Bay-Delta Program, 1999). Despite these changes, the system still provides some critical habitat for birds migrating along the pacific flyway and foraging habitat for water birds, including loons (*Gavia* sp.), pelicans (*Pelecanus* sp.), gulls (*Larus* sp.), cormorants (*Phalacrocorax* sp.), and diving ducks (CALFED Bay-Delta Program, 1999). The quality of this habitat has continued to decline since the 1970's.

Figure 6. Delta Smelt

Source: U.S. Fish and Wildlife Service, 2008

PROJECT HISTORY

In 1994, the Framework Agreement was signed between the Governor's Water Policy Council and the Federal Ecosystem Directorate (ClubFed) which established the operating principles for developing a long-term solution to the Bay-Delta problems

(California Bay Delta Program, 2000). In December 1994, the State and Federal agencies and stakeholders signed the “Principles for Agreement on Bay-Delta Standards between the State of California and the Federal Government”, which laid forth interim measures for both environmental protection and regulatory stability in the Bay-Delta. In 1995, CALFED was formed. CALFED represented a cooperative involving 15 federal and state agencies. Organizational responsibilities were defined by their level of participation in the NEPA process:

- Lead Agency: a state or federal agency with principal responsibility to implement or approve the project
- Responsible Agency, a state agency, other than lead, with responsibility for carrying out or implementing the project
- Cooperating Agency, an agency with jurisdiction or special expertise

Participating agencies and their status for this effort are summarized (Table 2).

Agency	Role	Jurisdiction
California Department of Fish and Game	Responsible	State
California Department of Water Resources	Responsible	State
California Environmental Protection Agency	Responsible	State
California Resources Agency	Responsible (Lead State Agency)	State
California State Water Resources Control Board	Responsible	State
U.S. Army Corps of Engineers	Lead	Federal
U.S. Bureau of Land Management	Cooperating Agency	Federal
U.S. Bureau of Reclamation	Lead	Federal
U.S. Environmental Protection Agency	Lead	Federal
U.S. Forest Service	Cooperating Agency	Federal
U.S. Geological Survey	Cooperating Agency	Federal
U.S. National Marine Fisheries Services	Lead	Federal
U.S. Natural Resource Conservation Services	Lead	Federal
U.S. Western Area Power Administration	Cooperating Agency	Federal

Table 2. Summary of the CALFED Agencies, Their Role in the NEPA Process, and Jurisdiction

REGULATORY FRAMEWORK UNDER NEPA AND ESA

CALFED also anticipated preparation of a programmatic EIS/EIR in order to comply with NEPA. The agencies engaged in a three phase effort to (1) define issues and identify solutions (the Draft Programmatic EIS/EIR), (2) identify a preferred alternative (Final Programmatic EIS/EIR and ROD), and (3) implement the preferred alternative. The 1999 Draft Programmatic EIS/EIR was developed in response agency interest in the development of a preferred alternative. The proposed alternative was intended to include storage, conveyance, water use efficiency, ecosystem restoration, watershed management, levee system integrity, water transfers, and water quality management. A key aspect of the overall strategy was the modification of the timing and magnitude of flow to restore ecological processes and improve habitat for fish, wildlife, and flora within the system. By 2000, the Final Programmatic EIS/EIR, including a preferred alternative, and ROD were finalized.

The ROD established specific responsibilities with the expectation that the CALFED organizations would guide regional efforts and implement some projects under the CALFED umbrella; however, state staff would be responsible for implementation, including planning, project performance, financial planning and management, and public outreach. The Science portion of the program would be responsible for advising other parties. The ROD contemplated a 30-year implementation period. To guide implementation of the specific projects identified in the ROD, a series of milestones were established by specific study areas, such as:

- Watershed management
- Water transfers
- Water use efficiency
- Levee systems
- Water quality management
- Ecosystem restoration (referred to as the Ecosystem Restoration Program [ERP])
- Water storage

The program also anticipated a need for a Section 10 permit under the ESA (CALFED, 1997). The Habitat Conservation Plan (HCP) under Section 10 of the ESA and Natural Communities Conservation Plans (NCCP) were anticipated to guide implementation (State of California, 2006). In a supplemental Notice of Intent (NOI), the Bureau of Interior identified three options to allow the agency to comply with ESA:

1. *Standard HCP: Develop a comprehensive HCP that would address all reasonable and foreseeable activities and associated impacts under consideration for the program. Assurances to appropriate entities would be commensurate with the level of specificity and detail provided in the HCP.*
2. *Phased HCP with Conditioned Permit: Develop an initial HCP for the Bay-Delta Program which addresses all known actions; supplemental HCPs (and appropriate CEQA and NEPA compliance) would be developed in the future as unknown/undefined program components became defined. Upon determination by the Services that issuance criteria have been met, an incidental take permit for the whole Bay-Delta Program would be issued; the permit would be conditioned to become effective in stages corresponding to approval of supplemental HCPs. Assurances to appropriate entities would become effective in stages.*
3. *Phased HCP with Permit Amendments: Develop an initial HCP for the Bay-Delta Program which covers all known actions; subsequent supplemental HCPs (and appropriate CEQA and NEPA compliance) would be developed in the future as unknown/undefined program components became defined. An incidental take permit, covering only those actions included in the initial HCP, would be issued upon approval of the initial HCP. Permit amendments would be processed as supplemental HCP's were approved. Assurances would be provided to appropriate entities only for that portion of the overall Program as covered by each permit or amended permit.*

(Bureau of Interior Management, 1997)

A subcomponent of the planning process, the Multi-Species Conservation Strategy (MSCS)-ERP Milestones contained a list of ecosystem restoration and water quality actions, designed to address the needs of specific species, including the Delta Smelt. These actions were expected to make significant progress toward restoration and recovery of covered species, including the Delta Smelt. The Plan focused upon implementation (Years 1 through 5 [2001-2006]) followed by an assessment in Year 6 (2007). The assessment was designed to evaluate if implementation occurred in a manner and to an extent sufficient to sustain programmatic federal and state endangered species acts. The evaluation was also expected to document NCCPP and HCP compliance for all Program elements. A more succinct summary of the key questions the assessment was intended to address was established by the agency: "Should additional surface storage be constructed in the Delta's watershed? Is the conveyance of water through the Delta to other parts of the state still working?" (California Bay Delta Program, 2000) Following the assessment, the program would have been subject to a review of its effectiveness every 7 years (State of California, 2006).

AM FRAMEWORK

The AM Framework, established in these documents, was established in part by a series of principles and associated policy implications (Healey, 2007). The principles included recognitions of the human and natural environmental processes and conditions within the Delta[7]. Prior to initiation of the project, the factors that limited abundance and productivity of specific species were not well understood. To address this, the program established a list of species-specific analyses required by the program to identify these factors and develop specific solutions. Specific factors of interest included water quality, entrainment, water surface level and movement, species interactions, and habitat. These issues were to be addressed during implementation.

[7] The adaptive management framework specifically incorporated the concerns already identified for the Basin. These include the following. A combination of changes in hydrologic regimes due to water withdrawals and reduced water return flows, decreases in water quality due to those hydrologic regime changes and storm water runoff, urbanization resulting in losses of wetland habitat, entrainment due to water intakes, and sedimentation created by urbanization, agricultural drainage, and channel modifications had severely affected the regions' habitat (CALFED Bay-Delta Program, 1999). The changes in hydrologic regimes had also modified salinity gradients. The presence of water priority chemicals, including heavy metals, has also had a severe effect on plankton within the Basin.

Implementation

In 2003, the Legislature created the California Bay-Delta Authority (CBDA) to coordinate and oversee planning and implementation of the CALFED Bay-Delta Program among its 15 participating state and federal agencies (State of California, 2006). CALFED was a division of state government, which was established to support the program and its AM Framework. In their 2010 article evaluating the effectiveness of CALFED, David Booher and Judith Innes argue that CALFED consisted of a complex adaptive network (CAN) which was limited by some informal policy-making approaches (Booher, 2010). "From 1994–2003, in an unconventional and sometimes messy way, CALFED implemented numerous innovative actions to manage water resources adaptively in this contested context." (Booher, 2010) CALFED was led by a policy group of executives from individual state agencies and federal agencies which were officially accountable to the governor and U.S. Secretary of Interior. A series of ad hoc tasks groups were established and modified over time. Four groups provided advice to the policy group:

- Operations Group (Ops) which coordinated operations of the water projects
- A water supply alternatives evaluation group
- A team to evaluate effects of water diversions on fisheries
- Coordinating team

The CALFED Bay-Delta Advisory Council (BDAC) became a forum for stakeholder involvement and vetted several issues. The results of these discussions were then communicated to the larger organization. As a result of these efforts, the decision making and implementation process, the program was greatly accelerated. However, many of the processes were informal in nature and individual organizations retained their own specific objectives and goals.

Following the establishment of CALFED, more quantitative tools were developed to evaluate potential projects within the Bay-Delta and their potential effects on specific species. This effort also provided information to allow refinement of conceptual, programmatic projects prior to implementation. The *Delta Regional Ecosystem Restoration Implementation Plan* (DRERIP) provided the basis for those studies, including development of conceptual models (State of California, 2007). The conceptual models developed under this program included an assessment of the factors in relationship to specific species and their life cycles. In 2007 and 2008, work products under the DRERIP included development of conceptual models and additional research.

The DRERIP also identified a series of habitat restoration projects. The document also established requirements for financial management, performance-based program management, program priorities, and independent review. An independent science review board was formed.

CALFED Faces The Perfect Storm

In 2006, CALFED became subject to criticism from the California legislature (California Legislative Analyst's Office, 2006). Criticism included the lack of long-range financial planning, the program's lack of focus and priorities, and the program's lack of a performance orientation. This criticism followed two 2005 reports which recommended a series of internal management initiatives including greater accountability to the governor and performance monitoring (Little Hoover Commission, 2005) (KPMG, 2005). A revised long-term plan was submitted by CALFED which also received severe criticisms for unrealistic funding targets, and the Governor began to take measures to develop policies to aid in maintaining the program on a reduced level. Public opinion also waned with regard the long-term future of the program as envisioned at that time:

> *The Governor's proposal has $49 million allocated to the Delta Stewardship Council from existing bond funds and reimbursements from other state agencies. But an apparent surprise is that the funding would also continue CALFED activities (California Bay Delta Program) – a failed project, committee members Lois Wolk, D-Davis, and Dave Cogdill, R-Modesto, did not hesitate to point out. What's more, CALFED staff members seem to be running the Delta Council show. Governor Gray Davis created CALFED in 2000 to resolve conflicts between various water agencies. But in 2006, the LAO (Legislative Analysts Office) reported that CALFED failed to develop a viable long-term finance plan, as required by the Legislature, as well as exhibited a "lack of focus and priorities" and "lack of a performance orientation." The analysts claimed that CALFED had strayed from its mission and instead expanded into a fully operational state agency that needlessly overlapped the already existing Department of Water Resources. The LAO recommended an overhaul of CALFED with more defined as well as limited responsibilities.*
>
> (CALWatchDog, 2010)

By 2007 (the deadline for the ROD required assessment); three major initiatives were underway to meet the deadline and to establish a strategy to sustain the problem-riddled Delta into the future (CALFED, 2007). Additionally, there were numerous studies underway to deal with specific Delta issues. And, then, in 2008, a series of challenges referred to as a "perfect storm of political and environmental forces" confronted CALFED (Frank, 2010). These included:

- The Delta Smelt continued to suffer from marked decline (and the BO published by the USFWS further regulated and reduced the availability of water resources within California)
- Litigation regarding the ESA resulted in court-ordered reductions in water deliveries for specific projects
- Research findings by the Public Policy Institute of California (PPIC) in 2007 and 2008 influenced state leaders
- Three successive years of drought reduced water deliveries for state and federal water projects and create urgency for water resource project deliberations
- Findings of the Governor's Delta Vision Blue Ribbon Task Force influenced state legislation
- Protracted political gridlock over the budget and dissatisfaction with the program in the media and general public also compromised the program

(Frank, 2010)

During that same year (in June), the Department of Water Resources (DWR) announced its intention to prepare a Draft Initial Study and Mitigated Negative Declaration for its own programs (CALFED, 2007). A series of legislative issues resulted in a restructuring of the CALFED program and its resurrection as a new agency (Frank, 2010).

DELTA HABITAT CONSERVATION AND CONVEYANCE PROGRAM: A NEW BEGINNING

In 2008, the Governor of California formed the Delta Habitat Conservation and Conveyance Program (DHCCP) to continue the mission of CALFED and protect the Delta Smelt, an endangered species (State of California, 2010). The DHCCP is designed to protect the Delta by prompting studies to assess potential habitat restoration and water conveyance options. DHCCP will conduct an environmental review of the Bay Delta Conservation Plan (BDCP), which is intended to be a joint HCP and NCCP. The lead agencies conducting the joint environmental review are DWR for California, and U.S. Bureau of Reclamation, USFWS, and National Oceanic and Atmospheric Administration for the federal government. The DHCCP will:

- *Analyze BDCP proposed actions and alternatives to those actions through a formal EIR/EIS process.*
- *Analyze options and consider areas of concern presented by the public during the EIR/EIS process.*
- *Develop engineering options for habitat restoration, other stressors, and water conveyance.* (DHCPP, 2010)

The DHCCP is anticipated to "analyze BDCP proposed actions and alternatives to those actions through a formal EIR/EIS process; analyze options and consider areas of concern presented by the public during the EIR/EIS process; and develop engineering options for habitat restoration, other stressors, and water conveyance" (State of California, 2010). The Draft EIS will be issued in late 2010 followed by an implementation plan in 2012. Portions of the EIS/EIR have been published in anticipation of the future release for public comment. This effort has also been extensively reviewed.

1994 -1995

- Framework Agreement Signed and CALFED established as an interagency task force

1999

- Draft Programmatic EIS/EIR Publishedcy task force

2000

- Issued Final Programmatic EIS/EIR (July)
- Issued Programmatic EIS/EIR Record of Decision (August)

2003

- Legislation establishes the CBDA to Aid Implementation

2006

- CALFED was subject to criticism by the California Legislature and Legislative Analyst's Office
- CALFED updated planning efforts to address concerns
- The HCP under Section 10 of the ESA and NCCP under the California Endangered Species Act was planned

2007

- Key Decisions required under the ROD were to be addressed by the Program
- Three initiatives by CALFED underway to address requirements

2008

- CA Department of Water Resources announced it intentions to prepare a Draft Initial Study and Mitigated Negative Declaration
- Governor Forms the DHCCP

2009

- Extensive Reviews of the Adaptive Management Approach Conducted

Late 2010

- Draft EIS for the DHCCP anticipated

Figure 7. Bay-Delta Timeline (1994-2010)

In February 2009, an independent review document regarding adaptive management identified some specific, new principles for the effort. They included:

- *The scope and degree of reversibility of each proposed action (i.e., conservation measure) determines the form of adaptive management that can be applied (e.g., "active" or experimental adaptive management versus "passive" adaptive management).*
- *The knowledge base about the ecosystem is key to decisions about what to do and what to monitor, and includes all relevant information, not just that derived from monitoring and analysis within the context of BDCP.*
- *Program goals should relate directly to the problems being addressed and provide the intent behind the conservation measures; objectives should correspond to measurable, predicted outcomes.*
- *Models should be used to formalize the knowledge base, develop expectations of future conditions and conservation outcomes that can be tested by monitoring and analysis, assess the likelihood of various outcomes, and identify tradeoffs among conservation measures.*
- *Monitoring should be targeted at specific mechanisms thought to underlie the conservation measures, and must be integrated with an explicitly funded program for assessing the resulting data.*
- *Prioritization and sequencing of conservation measures should be assessed at multiple steps in the adaptive management cycle.*
- *Specifically targeted institutional arrangements are required to establish effective feedback mechanisms to inform decisions about whether to retain, modify, or replace conservation measures.*
- *A dedicated, highly skilled agent (person, team, office) is essential to assimilate knowledge from monitoring and technical studies and make recommendations to senior decision makers regarding programmatic changes.*

(Independent Science Advisors, 2009)

The overall AM approach recommends the incorporation of active AM without recommendations on its integration into federal permitting and financial processes. The approach also recommends more extensive data collection, more careful integration of objectives and evaluation techniques, and more specific modeling and monitoring efforts.

It also recommends focus upon conservation measures resulting from the additional modeling and monitoring.

The incorporation of conceptual, statistical, and process models is a key recommendation for the program. It was recommended that conceptual models be used "…to make clear the expected links between actions and outcomes, the roles of other factors, the degree of confidence in the outcomes, and potential tradeoffs (e.g., among species or alternative conservation measures)" (Independent Science Advisors, 2009). Statistical models would be utilized to "….characterize empirically how a system works" based upon the range of condition for which data collection has occurred (Independent Science Advisors, 2009). However, process models would be based in the underlying mechanisms to predict system responses to environmental change by extrapolating beyond available data although the calibration and validation of models involves uncertainty.

The advisory panel recommended specific monitoring plans for conservation measures that are implemented in parallel with the projects. The panel's recommendation is based in part on the National Research Council's (1990) three classes or purposes of monitoring: compliance, model verification, and trend. The panel suggested four types of monitoring:

- *Compliance* monitoring is built into permit requirements and focuses on whether the conservation measures are being implemented as planned.
- *Performance* monitoring identifies whether individual conservation measures are achieving their expected outcomes or targets.

- *Mechanistic* monitoring demonstrates whether the mechanisms thought to link conservation measures to desired outcomes are working as predicted.
- *System-level* monitoring is used to identify the degree of success of the entire program (i.e., the cumulative effects of numerous conservation measures) relative to ultimate desired outcomes as described in the BDCP documents. This requires a sustained, long-term commitment to monitoring of critical features of the whole system, rather than the response of a single measure in the vicinity of a single locality. (Independent Science Advisors, 2009)

The Draft EIR/EIS for this effort should be released in early 2011 with a complete Habitat Conservation Plan and final AM strategy in 2012 which would allow the program to obtain final permits. The early design of the project is also in progress. The cost-benefit analyses techniques and evaluation of alternatives is also under development. In parallel, public opinion from some special interest groups seems to echo the same sentiment:

> *We will never fully understand the complex natural mechanisms in the Delta. That realization is inevitable, given that we now know that the Delta is subject to powerful forces, such as invasive species, climate change, earthquakes and subsidence that will shape the Delta over time. This means that, when it comes to our regulatory system in the Delta, we can never (as a famous TV pitch man says) "Set it and forget it." Today, the Bay-Delta is subject to a patchwork of adaptive management and old-school regulatory approaches. If we are to succeed in managing the Bay-Delta for the co-equal goals of ecosystem health and water supply, we must reform our institutions so that they are capable of fully integrated adaptive management. The Delta Vision Task Force strongly supported an adaptive management approach to the Delta.…The old approach to regulation – establishing relatively fixed environmental standards and simply monitoring implementation – is still seen at the State Water Resources Control Board. The bulk of the State Board's water quality standards for the Delta were negotiated and put in place 15 years ago. State law calls for a triennial review of these standards, to respond to on-the-ground developments and improved scientific understanding. However, the State Board has been remarkably slow in updating those standards and in responding to the ongoing collapse of the Delta ecosystem. This is a far cry from the agile, science-driven approach that is the goal of adaptive management. The existing SWRCB standards are widely recognized as inadequate to protect the beneficial uses of the Delta. These standards must be improved. Indeed, Delta Vision specifically called for stronger State Board*

standards to provide greater outflow at critical times. But it's not just the standards that must be improved; the old, rigid approach to regulation must adapt as well. (Nelson B. , 2009)

LESSONS LEARNED

The research does suggest that the CALFED efforts and its successors did advance some aspects of the AM concept as well as key items which could benefit future efforts: the introduction of the complex adaptive network concept, demonstration of the legal sufficiency of programmatic approaches like CALFED under the California Environmental Quality Act (CEQA), and the need for aggressive public involvement for regional efforts with diverse and conflicting stakeholders. The following sections summarize these issues.

Complex Adaptive Network

CALFED's Bay-Delta Advisory Council (BDAC) represented a public involvement forum for stakeholders as well as a vetting body for collaborating interactions and decision-making based upon input from subcommittees to BDAC. In a critique, the authors established the working definition of a collaborative CAN (established in part by the operations of CALFED): interdependent network clusters under distributed control with an open boundary and shared authority. The authors also identified specific programmatic advancements resulting from CALFED (Booher, 2010):

- Establishing a distributed network structure, involving multiple agencies

- Establishing a basis for collaborative interaction heuristics[8] by allowing individual agencies (local and non-local) to implement individual actions under the Programmatic EIS/EIR
- Responding to permitting requirements by establishing a nonlinear planning method, involving programmatic NEPA documentation, a ROD that guided future processes rather than dictating a solution, and concurrent planning methods, including the DRERIP
- Promoting self-organizing system behavior, where work processes were established over time

At the conclusion of the study, the authors declined to evaluate the ultimate success of the CALFED effort. They do conclude that the CAN will become increasingly common in environmental restoration projects. They also defined the role of the manager as a mediator and process manager within CANs "who selects agents and resources, influences conditions to guide interactions, and provides opportunities for the agents to interact" (Booher, 2010). Other analysts suggest that the CAN structure-if not established properly-can lead to a lack of clear roles and accountability (Little Hoover Commission, 2005).

These views were shared by others:

> *As a mechanism for developing infrastructure, transporting water, and meeting diverse water demands of the 20th century, this institutional system has worked well. As for a verdict on its capacity to coordinate strategies for collectively*

[8] Heuristics is defined as "encouraging a person to learn, discover, understand, or solve problems on his or her own, as by experimenting, evaluating possible answers or solutions, or by trial and error." (Dictionary, 2010)

> *resolving 21st century ecological crises, long-term drought, climate change, and urban growth, however, the jury is still out…. Clearly, no easy solution exists for the Bay Delta and for California's water crises more broadly. For too many years, the state has been limping along with ad-hoc or locally driven solutions, such as water conservation restrictions, small-scale water transfers for species, or band-aid fixes to delta levees. The institutional and policy responses that are needed today are likely to require bold leadership and extensive inter-jurisdictional coordination and cooperation. With the CALFED process hamstrung, the state appears to be sorely lacking in the institutional mechanisms to bring these ideas to the forefront and garner cross-sectoral support. Will new dams or a new canal address these problems, or only create further fractures and debates? Historically, crisis is an opportunity to make something happen. And California's Bay Delta is in such a moment of crisis. Policymakers in California are paying attention, but the question is whether or not the attention is focused in the right direction.*
>
> (Heikkila, 2009)

Management Trap

Conversations with individuals in the process suggest the management trap also affected the process. The program was considered very instrumental in the development of conceptual models and integration of them into the decision-making process (Hastings, 2010). A key success of this effort was to establish the "importance of inserting science into the process" and the importance of ongoing research to support the decision-making process (Hastings, 2010). Establishing a common definition and a group vision for governance were considered an issue not only for this program but other adaptive management efforts (Hastings, 2010). The program also faced the challenge of moving decision-makers thinking beyond a "steady state" approach to embrace uncertainty and address complex issues (Mueller-Solger, 2010).

Other challenges for the Delta, beyond the complexity of an extremely altered and complex system, focused upon governance. Following the establishment of the new

Delta Habitat Conservation and Conveyance Program, the restoration's efforts shifted from developing specific plans for regional components to improvement of governance structures and defining approaches in an effort to reduce ambiguity. The program is now focused upon developing an adequate working definition of adaptive management and establishing a strong governance program, particularly explicit connections between conceptual models, monitoring, and decision-making (Hastings, 2010).

Further refinements of that effort are expected to include greater involvement of independent reviewers; extensive and explicit use of models to formalize knowledge and "…select, design, and predict outcomes of projects to be implemented and monitored"; and more formal processes to collect data and alter actions and revised goals (Independent Science Advisors, 2009). Improvements in the regional integration of models or systems would be designed to identify conflicts between conceptual models or work approaches and project synergies (opportunities to reduce costs and increase benefit by complementary efforts) (Independent Science Advisors, 2009).

Legal Sufficiency

CALFED was considered controversial and involved some legal challenges under the California Environmental Quality Act (CEQA) (Abbott, 2008). In 2000, CALFED certified a programmatic EIR/EIS which received a timely legal challenge after which the trial court upheld the adequacy of document. Later, the Court of Appeal ruled otherwise, concluding that the EIR was inadequate because of the "…failure to evaluate an alternative with reduced water exports, the failure to identify future potential sources of water, and the lack of detail on the Environmental Water Account, a program within CALFED" (Abbott, 2008).

The California Supreme Court (Court) subsequently granted review. On June 5, 2008, the Court issued an opinion, which affirmed the legal adequacy of the programmatic document. The legal opinion indicated that CEQA does not mandate that a first-tier programmatic EIR (which describes the overall program and major elements and effects) identify with certainty particular sources of water for second-tier (or later) projects that will be further analyzed before implementation.

The case also addressed the incorporation of new information which was a key aspect of the AM.

> *In an interesting and potentially disastrous case of bad timing, some information regarding the Water Account became available immediately before certification of the first tier EIR. This generated the obvious argument that the EIR had to include this new more detailed information. The Court struck a blow for practicality when it recognized that the agency should not be effectively punished for releasing more current information. Rather, the Court held that if the first tier EIR was not required to consider this information, then the fact that some of the information became available pre-certification did not become a compulsory basis to expand the first tier EIR.* (Abbott, 2008)

The lawsuit demonstrates a lack of public support for the effort, which was further confirmed by Mr. Abbott's blog:

> *The Delta, the confluence of the Sacramento and San Joaquin rivers, is ground zero in the debate over California water. It seems like everyone has a dog in the fight, including farmers inside and outside of the Delta, municipalities, water contractors, the sport fishing industry and environmentalists.* (Abbott, 2008)

Public Involvement

The comments of the public illustrate a mixed opinion of the effort as well as recognition of these issues:

> *Both for its technological and institutional innovations and for its history of conflicts, California's water system has been one of the most observed in the world….CALFED is likely the most ambitious experiment in collaborative environmental policy and adaptive management the world has seen to date. This Issue moves beyond the celebratory tone of other analyses of collaborative, adaptive management and looks closer into how collaborative networks work to produce innovation, and more importantly to reflect also on their inherent contradictions, limitations and "dark sides". While collaborative governance enhances mutual understandings and can be a source of innovation, it appears ill-suited to resolve alone the distributive dilemmas at the core of many water – and other environmental – conflicts. A lacuna in existing research concerns the institutional design of effective boundaries and linkages between democratic politics, legitimate authority, and adaptive governance, i.e. the mix of institutions that can provide sufficient responsibility, accountability and democratic legitimacy, without choking off the self-organizing interaction, shared learning, and communication that is at the heart of collaboration. A painful realization in the Delta is that environmental conservation and further growth may be fundamentally at odds; efficient win–win solutions, institutional or technological, seem insufficient to satisfy the competing demands posed upon the system. Radical decisions and changes might be necessary, but they seem unlikely under current institutional arrangements and political conditions.*
>
> (Legal Planet, 2010)

An independent review report also recommended the greater emphasis on integration of scientific and community goals (Independent Science Advisors, 2009).

COST-BENEFIT ANALYSES

The original premise for benefit-cost analyses under CALFED involved transitioning from a more goal-oriented perspective to a more defined and project-specific analysis in Phase II (Lang, 1996). In Phase II, modeling to identify benefits were correlated with feasibility cost estimates to estimate potential cost benefits (CALFED, 1997). These summaries were incorporated into the Draft EIS/EIR but did not elaborate fully on the methodology. On a related front, the implementation of the plan was also at risk due to poor financial planning and potential limitations of state funding:

> *The Council's plan is likely to be extraordinarily expensive. The back-of-the-envelope estimate kicking around the halls of the water world is that the plan could cost a total of $40 billion over several decades. That estimate is certainly wrong, but clearly, paying for this plan will be a major challenge. Financing the Delta Plan is another key to the success of the Delta Stewardship Council. Unfortunately, we have some recent history to learn from here. Despite consistent pressure from the legislature, the CALFED Bay-Delta Program failed to produce a credible finance plan. Its original plan assumed large contributions from the state and the federal budgets. These funds failed to appear in the generous quantities anticipated. Water users didn't fill the gap. Eventually, it became clear that much of the CALFED plan would not be implemented and the program lost credibility. The failure to write a credible financing plan was one of the reasons the legislature eliminated the CALFED program and created the Council.* (Nelson B. , 2010)

Since then, refining these requirements has been refocused under the reevaluation effort.

As the cost-benefit analysis is refined for the program, the process for managing cost effectiveness and evaluating progress is also under development (BDCP, 2010). Tools in the initial draft include tracking performance against cost through time.

South Florida Ecosystem Restoration

BACKGROUND

The Everglades, located in the southern portion of the Florida peninsula, encompass a regional watershed of 10,890 square miles and the Kissimmee-Okeechobee-Everglades Florida Bay system (Gunderson, Light, & and Holling, 1995). Historically, close to 8.9 million acres of Florida's southern peninsula was composed of interconnected wetlands; 4 million of which were known as the Everglades (Florida

Department of Environmental Protection, 2009) The Everglades National Forrest encompasses a majority of southern Florida and is located on the western coast of the state (Figure 8).

During the late 1880's, development of the area began in earnest. Severe hurricanes in the 1920's and 1940's resulted in the construction of the Central and South Florida (C&SF) Project which created thousands of miles of canals and 750 miles of levees (U.S. Army Corps of Engineers, South Florida Water Management District, and Partners, 2010). Construction was authorized by the federal government in 1948. During the late 1940's and 1950's, this and several other flood control projects were completed. The local population increased from 1950 to 1990 from approximately 0.75 million to 4 million residents (Gunderson, Light, & and Holling, 1995). In 2010, 7 million people reside in South Florida (Committee on Independent Scientific Review of Everglades Restoration Progress, National Research Council, 2010).

During the 20th century, the system experienced dramatic changes in land uses (in addition to the flood control projects) which altered the quality, quantity, and temporal and spatial distribution of water in the system (Gunderson & Light, 2006). Approximately 50 percent of the original Everglades ecosystem has been developed. The result has been characterized as highly-altered, remnant natural system with multiple human uses. Invasive species are also pervasive (Committee on Independent Scientific Review of Everglades Restoration Progress, National Research Council, 2010).

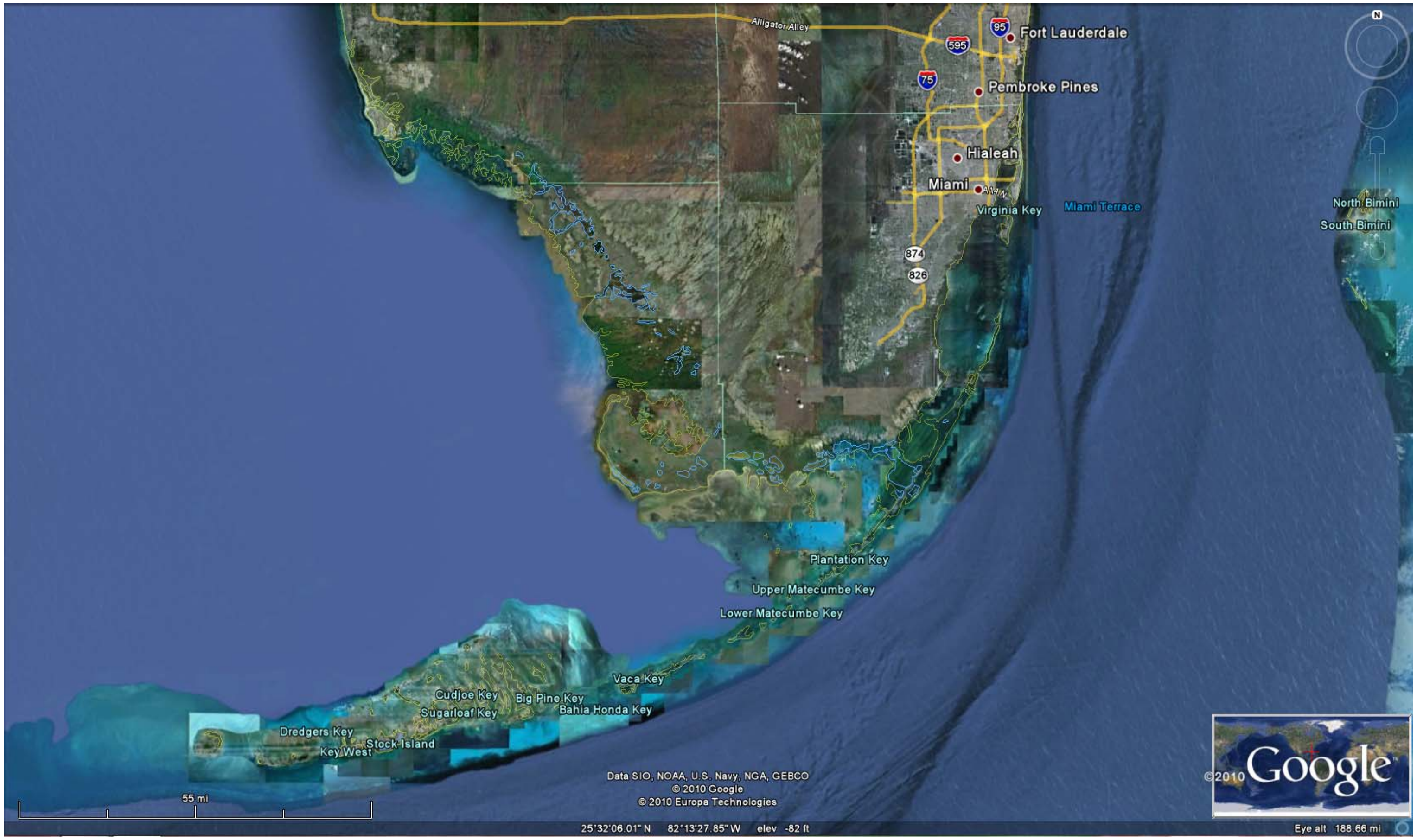

Figure 8. Aerial Satellite Photograph of Southern Florida

The Everglades' current land uses vary: dedicated agriculture (27 percent of the original area), water conservation areas (33 percent), urban areas (12 percent), the Everglades National Park (21 percent), and undeveloped areas (7 percent) (Gunderson, Light, & and Holling, 1995). The high demand for water has also compromised groundwater availability and flows to the Everglades and potential for subsidence and sea level rise remains a concern (U.S. Army Corps of Engineers, 1999). Citrus production dominates some of the sub-watersheds within the basin.

Figure 9. Representative Photo of an Undeveloped Everglades Marsh

Source: Florida Department of Environmental Protection

In addition to its status as a World Heritage Site, the Everglades National Park comprises much of the remaining temperate and subtropical habitat in South Florida (U.S. Army Corps of Engineers, 1999). The area consists of sawgrass sloughs, tropical hardwood hammocks, offshore coral reefs, mangrove forests, and a variety of water bodies. The upper Kissimmee River watershed consists of a variety of lakes and slough as well as the Kissimmee River and its broad floodplain (Committee on Independent Scientific Review of Everglades Restoration Progress, National Research Council, 2010).

Other water bodies include the extensive Lake Okeechobee, ridge and slough wetlands, and further south, the areas bays and estuaries. The area contains the largest continuous sawgrass prairie in the U.S., provides the largest most significant breeding grounds for tropical wading birds in North America, and supports 230,200 acres of mangrove forests and a nationally significant estuarine complex. Limestone geology and islands pervade the extremely low gradient area (1 to 2 inches per mile).

Prior to drainage of the area, the wetland landscapes typically consisted of swamp forests; sawgrass plains; mosaics of sawgrass, tree islands, and sloughs dominated by *Nymphaea*[9]; and marl-forming prairies and cypress stands. Upland landscapes typically consisted of pine flatwoods, pine rocklands, tropical hardwood hammocks, and xeric hammocks dominated by oaks. The coast consisted of shallow seagrass beds, riverine and fringe mangrove forests, intertidal flats, coral reefs, hard bottom communities, mud shallows, and shallow, open inshore areas.

Recognition of the ecological plight of the area began as early as the 1920's and received greater attention in 1947 with the publication of <u>The Everglades: River of Grass</u> and the dedication of the Everglades National Park (Committee on Independent Scientific Review of Everglades Restoration Progress, National Research Council, 2010). By 1995, officials recognized "South Florida is no longer sustainable on its present course." (U.S. Army Corps of Engineers, 1999). A total of 68 protected species (avian and non-avian) are at risk within the Everglades (USACE, SWFWD, and Partners, 2010).

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[9] An genus of aquatic plants.

Over the past 50 years, the Everglades experienced a decrease of 85 to 90 percent of wading birds (Lorez, 2010). Several species, such as Wood Storks (*Mycteria Americana)*, White Ibis[10], and Great and Snowy Egrets[11], were common in the mangrove forests prior to the 1960's (U.S. Army Corps of Engineers, Jacksonville District, and South Florida Water Management District, 2010). This decline has occurred as a result of direct development and diversions of water to support the growing human population (Committee on Independent Scientific Review of Everglades Restoration Progress, National Research Council, 2010). Due to the large catchment of the basin (more than 18,000 miles), the area is also extremely vulnerable to the effects of water pollution – both point or source pollutants and nonpoint sources including urban runoff. High concentrations of phosphorous, nitrogen, sulfate, mercury, and pesticides are evident throughout the basin's water bodies. Some of these species were selected to serve as indicator species for restoration efforts.

Identified as an indicator organisms for restoration efforts in 1999, the Wood Stork is listed as endangered by both the Florida Fish and Wildlife Service and the U.S. Fish and Wildlife Service (McLean, 2001). Due to its reliance freshwater and estuarine wetlands during the dry season, the Stork is particularly sensitive to poor water quality and over allocation of freshwater. Between 1985 and 1999, the Everglades supported 500-1,000 pairs.

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[10] The White Ibis (*Eudocimus albus*) is a state listed Species of Concern in Florida.
[11] Snowy egret (*Egretta thula*) is a state-listed Species of Concern in Florida.

The Roseate Spoonbill (*Platalea ajaja*), is identified as a Species of Special Concern by the Florida Fish and Wildlife Conservation Commission (McLean, 2001). The species has suffered a serious decline since the 1970's with an estimated 500-750 pairs remaining in the 1990's. The decline is largely attributed to a lack of foraging habitat (Lorez, 2010) in mangrove forests. The Roseate Spoonbill was identified as an indicator organism in 1999 (McLean, 2001). Conceptual models suggest that restoration of the mangrove estuarine transition zone, which could be accomplished in large part with an improved hydrologic regime, would greatly benefit the species (Lorez, 2010).

Figure 10. Image of the Roseate Spoonbill

Source: U.S. Geologic Survey

Other species are also of interest. High concentrations of phosphorous have also compromised the region by causing eutrophication and severe algal blooms in the estuaries, particularly the St. Lucie Estuary (McLean, 2001). These conditions have serious compromised American oyster populations. To protect the remaining healthy American oyster beds within the system, the program identified the species as an indicator organism for monitoring and program evaluation in 1999. Survival of other organisms were identified as performance standards for the program including sea grass, native trees, and commercial critical species including pink shrimp, Gray Snapper, and other game fish.

Project HistoryAs a result of severe conflicts within the basin, the USACE, the South Florida Water Management District (SFWMD), and the Everglades National Park initiated a series of restoration efforts. The goal of the effort is restore, protect, and preserve up to 18,000 square miles of south Florida and has been described as the world's largest restoration plan (USACE, SWFWD, and Partners, 2010). Each of these entities continues to play key roles in the restoration effort.

During its early phases, the Restoration effort exhibited the major phases of most restoration projects:

- Policy formation (exploitative phase where opportunists or restrategists may or do prevail)
- Policy maturation (conservation phase in which advocates for implementation prevail)
- Policy failure (crisis phase where policies and approaches may be compromised)
- Policy alternative generation (renewal phase where restoration efforts flourish)

(Gunderson, Light, & and Holling, 1995)

Early progress towards the last phase began as early as 1983 as the program established coupled heuristics (using a hierarchy [involving both biotic and atmospheric hierarchies] and system-phase dynamics [including management institutions]) to provide a framework between science and policy. The most recent restoration effort benefited from this early work and is the main focus of the review associated with the Everglades. It also benefits from restoration efforts or foundation projects begun immediately before the CERP (Committee on Independent Scientific Review of Everglades Restoration Progress, National Research Council, 2010).

The Corps and its partners have been working on the restoration of the Kissimmee River since the late 1990s that will restore wildlife habitat in the northern part of the greater Everglades system (USACE, SWFWD, and Partners, 2010). The Kissimmee River Restoration has been recognized as one of the most successful AM programs in the world (Dahm, 2010). Two other projects are currently underway to return water flows to Everglades National Park through Shark River and Taylor Sloughs, two historically important water sources for the system.

During the 1990's, agencies were also re-evaluating the C&SF Project. The 1992 and 1996 Water Resources Development Acts (WRDAs) provided the USACE with authorization to re-evaluate performance and impacts. It also authorized the USCE to recommend improvements and or modifications to the project in order to restore the south Florida ecosystem and to provide for other water resource needs.

Established in 1996, the South Florida Ecosystem Restoration (SFER) is engaged in an extensive effort to preserve and restore habitat within Southern Florida (South Florida Ecosystem Restoration Task Force, 2010). The program represents a partnership between the USACE, SFWMD, and other federal, state, local, and tribal entities. The effort involves several technical task forces that evaluate information and initiatives to ensure consistency with the original program objectives (South Florida Restoration Task Force, 2010).

The SFER program continued to evolve as the Comprehensive Everglades Restoration Plan (CERP) was developed in the late 1990's and authorized for implementation by Congress in 2000. The ongoing CERP-related programs also involve an extensive partnership of agencies. (Table 3).

Agency	Role	Jurisdiction
Broward County, FL	Responsible	Local
Florida Department of Agriculture and Consumer Services	Responsible	State
Florida Department of Environmental Protection	Responsible	State
Florida Game and Fresh Water Fish Commission	Responsible	State
Lee County, FL	Responsible	Local
Martin County, FL	Responsible	Local
Miami-Dade County, FL	Responsible	Local
Miccosukee Nation	Cooperating	Tribal
National Marine Fisheries Service	Cooperating	Federal
National Park Service	Cooperating	Federal
Natural Resources Conservation Service	Cooperating	Federal
Palm Beach County, FL	Responsible	Local
Seminole Nation	Cooperating	Tribal
South Florida Water Management District	Responsible	State (Lead)
U.S. Army Corps of Engineers	Lead	Federal
U.S. Fish and Wildlife Service	Cooperating	Federal
U.S. Geologic Survey	Cooperating	Federal

Table 3. Summary of CERP Participating Agencies

The CERP provided a framework and guides efforts to restore, protect, and preserve the water resources of central and southern Florida, including the Everglades, and guide implementation of the C&SF Project which was already underway (CERP, 2010). The document also provides a summary of the current conditions within the restoration area, threats to the area, and the major goals of the effort. The CERP also responded to specific issues raised by USFWS. 1n 1998, the USFWS issued a programmatic BO covering 18 federally listed species which could be affected by the CERP. Some of these species improved between 1998 and 2009 and were delisted. Five of the species continue to decline (including upland species): eastern Indigo snake (*Drymachon corais couperi*), Florida grasshopper sparrow (*Ammodramus savannarum floridanus*), Florida scrub jay (*Apelocoma coerulescens*), Everglades snail kite (*Rostrhamus sociabilis plumbeus*), and Wood Stork[12] (Committee on Independent Scientific Review of Everglades Restoration Progress, National Research Council, 2010). Finalization of the CERP was not completed until issues involving these and other species were resolved.

The resulting CERP was designed to capture, store and redistribute fresh water previously lost to tide and to regulate the quality, quantity, timing and distribution of water flows. Approved by WRDA 2000, the CERP implementation includes more than 60 elements and will require 30 years for completion. The effort included a requirement for biennial (every 2 years) evaluations of the program by the National Academies of Science (Committee on Independent Scientific Review of Everglades Restoration Progress, National Research Council, 2010). This $7.8 billion investment benefited from extensive synthesis of scientific data during the 1990's (Gunderson & Light, 2006). Major plan components include:

[12] This Wood Stork continued to be listed as declining although the Wood Stork did experience improvements in its population in South Florida between 2008 and 2009.

- Surface Water Storage Reservoirs which would provide approximately 1.5 million acre-feet[13] of storage throughout the system
- Water Preserve Areas
- Management of Lake Okeechobee as an Ecological Resource
- Improved Water Deliveries to the Estuaries and other portions of the Everglades
- Underground Water Storage, including use of aquifer storage and recovery which would store water about 1,000 feet underground using wells[14] and abandoned quarries
- Stormwater Treatment Wetlands which would treat agricultural and urban runoff prior to entering natural wetlands
- Removal of Barriers to Sheet flow including 240 miles of levees and canals
- Seepage management, including lining of canals with impervious materials to prevent unnecessary seepage
- Reuse of Wastewater and conservation within urban areas
- Pilot Projects
- Additional Feasibility Studies

(Committee on Independent Scientific Review of Everglades Restoration Progress, National Research Council, 2010)

[13] An acre-foot is defined as the area of one acre filled to a depth of one foot over 43,560 cubic feet or 1233.5 cubic meters of water (Farlex, Inc., 2010).

[14] This approach had not been tested at a sufficient scale for the regional effort in 2010 (Committee on Independent Scientific Review of Everglades Restoration Progress, National Research Council, 2010).

Florida also has additional regulatory requirements to preserve and manage coastal areas including aquatic ecological areas in addition to the federal coastal consistency certification requirements (Florida Department of Environmental Protection, 2010). A summary of the restoration's history is provided (Figure 11).

ADAPTIVE MANAGEMENT FRAMEWORK

A key premise of the restoration effort is that improvements in the hydrologic regimen and water quality will be sufficient to result in marked improvements of habitat and species survival (Committee on Independent Scientific Review of Everglades Restoration Progress, National Research Council, 2010). This premise is supported by a variety of numerical models and prior research. The fundamental goals of the AM framework program include:

- Anticipating possible future uncertainties and contingencies during planning of qualitatively different alternatives
- Utilizing science-based approaches to increase knowledge over time
- Designing "robust" projects which can be adapted to uncertain or changing conditions over time
- Building shared understanding through collaboration and conflict resolution
- Reconciling competing objectives to benefit ecology and society

The decision-framework of the CERP linked alternatives or projects to monitoring, targets or performance measures, and potential management options to ensure the project's goals and objectives are reached. To achieve these AM protocols, a series of monitoring programs were established. As individual projects are implemented, the uncertainty regarding the system's functions should gradually decrease. The resulting monitoring results would then be used to generate reliable systemic models. To implement these work approaches, a series of work groups have been established.

The REstoration, Coordination, and VERification (RECOVER) is a multi-agency, multi-disciplinary team of scientists, modelers, planners, and resource specialists responsible for organizing, analyzing, and applying scientific and technical information to support the goals of the CERP (Committee on Independent Scientific Review of Everglades Restoration Progress, National Research Council, 2010). The program's recommendations recognize the limitations of numerical models, using current technology, to characterize the predictive power of ecological responses to management actions, especially regionally (RECOVER, 2006). These approaches are complemented by the implementation of the Monitoring and Assessing System Performance (MAP), which evaluates hypotheses for the system and compliance with targets for implementation.

1983

- Modern restoration of the Everglades begins

1992 -1996

- 1992 WRDA authorized re-evaluation of the C&SF under the Civil Works Process
- 1996 WRDA continues that funding
- SFER established

1999

- Kissimmee River restoration underway
- Several federally and state protected species and other ecologically and commercially significant species were identified as indicator species
- A combined EIS/Feasibility Study is published

2000

- Funding for implementation was authorized by Congress under WRDA 2000
- CERP began

2004

- Biennial reviews of the program began

2010

- 68 protected species are at risk in the Everglades
- 85 to 90 percent of the pre-develoment wading bird population has been lost
- The Third Biennial Evaluaton for the program is published

Figure 11. Everglades Restoration Timeline

These include the evaluation of indicator organisms identified earlier. RECOVER also includes a specific program to better unify and standardize ecological benefit quantification and minimize inconsistencies referred to as the Benefits Evaluation Analysis Methodology (BEAM) (USACE, SFWMD, and other partners, 2010).

As projects are implemented, the reporting mechanisms allow for reevaluation of alternatives and reassessment of those activities within the context of the larger regulatory and Civil Works processes. This allows an effective evaluation of performance measurements and provides updated information to the Systems Planning and Operations Team (SPOT). The SPOT aggressively addresses technical and legal issues within the context of the entire program. Formal forums allow for dialogue between scientists and managers throughout the program. Another level of quality control is provided by the CERP Quality Review Board which oversees authorization of specific projects and schedules.

These work groups have also been supported by additional funding from the state of Florida to accelerate implementation efforts (Committee on Independent Scientific Review of Everglades Restoration Progress, National Research Council, 2010).

IMPLEMENTATION

The CERP relies upon these feedback mechanisms as well as the NEPA and Civil Works Guidance for its implementation. Individual projects are tiered off of the programmatic EIS and Civil Works feasibility studies. During 2010, several major projects were underway including:

- Kissimmee River Restoration Project, which will be completed in 2013 and involves efforts to reestablish the historical river-floodplain system and evaluate ecological responses to the restoration
- Everglades Construction Project, which involves construction of storm water treatment areas
- Modifications to the C&SF, which would improve hydrologic conditions for Taylor Slough and the Rocky Glades
- Modified water deliveries to Everglades National Park Project, which would restore more natural hydrologic conditions to the park
- Northern Everglades and Estuaries Protection Program, which would expand protections to the Lake Okeechobee watershed and the Caloosahatchee and St. Lucie estuaries

The performance goals for projects and their operations were established and are reevaluated with the recognition of evolving science within the program. Each project encompasses a range of outcomes and operational strategies to achieve specific objectives, including ecological restoration goals (LoSchiavo, 2010). An example of such a protocol is the related Regulation Schedule for Lake Okeechobee, which controls lake regulatory levels by High, Intermediate, Low, Base flow, and Beneficial uses levels or sub bands (South Florida Water Management District, 2010). These conditions have been established to address ecological and human needs as well as variable water availability (due to hurricane and droughts) and climatic conditions which influence lake levels. Public meetings and real-time feedback on Lake Okeechobee as well as other monitoring are used to not only improve policies but also evaluate operations.

LESSONS LEARNED

On September 23rd, 2010, the National Research Council released its third biennial evaluation of the Comprehensive Everglades Restoration Plan (U.S. Army Corps of Engineers Jacksonville District, 2010). The Committee on the Independent Scientific Review of the Everglades Restoration Progress prepared the report, which is required every two years by Congress as mandated in WRDA 2000. Under the Congressional mandate, the reports evaluate:

- progress in restoring the natural system, "which is defined by section 601(a) of WRDA 2000 as all the land and water managed by the federal government and state within the South Florida ecosystem";
- significant accomplishments of the effort
- specific scientific and engineering issues that may impact progress and the ability to achieve natural system restoration goals
- monitoring and assessment protocols to be used for evaluation of program progress "(e.g., CERP performance measures, annual assessment reports, assessment strategies, etc.)"

(Committee on Independent Scientific Review of Everglades Restoration Progress, National Research Council, 2010)

The report acknowledged that political division regarding the program did compromise restoration efforts between 2000 and 2008 and initial ecological benefits were limited as a result. Water quality improvements were less than expected and suggest a more complex system than originally anticipated. In general, the report found that the program has made limited progress overall and still lacks the necessary environmental and societal changes necessary to achieve accelerated progress. Other observations include the following.

- Lack of public involvement to assess the adaptive management approach has characterized the effort.
- The recently completed Biscayne Bay Coastal Wetlands Phase 1 Draft Integrated PIR/EIS includes an Incremental Adaptive Restoration process, which includes identifying key uncertainties, management alternatives and associated costs, and hypothesis-based assessment protocols tied to specific performance measures. The committee preferred this approach over other efforts.
- The committee also criticized the program's reliance on a passive adaptive approach which does not have sufficient scientific and information management capabilities to sufficient integrate effective adaptive management.
- The Committee also encouraged increased focus upon the communication of new information to improve scientific decision-making and ensure greater integration of new data.

These comments follow an earlier assessment by the NRC regarding the Everglades effort which recommends further refinement of the Monitoring and Assessment Plan (MAP) to address some key considerations:

- Clear restoration goals and targets
- Sound baseline description and conceptualization of the system
- Effective process for learning from future management actions
- Explicit feedback mechanisms for refining and improving management based on the learning process

(Council, 2003)

Feedback from individuals involved in the effort also suggests other important considerations in the AM process. Strong inter-agency communications and planning must be coupled with flexibility in operations to achieve systematic goals (LoSchiavo, 2010). This integration needs to also include focus of research efforts to address specific, prioritized issues which might include resolution of experimental errors or uncertainty (LoSchiavo, 2010). The recognition of uncertainty (scientific versus policy) and flexibility to address the constraints of the Civil Works process were also considered very important (LoSchiavo, 2010). Perhaps the most significant challenge for adaptive management is the diverse and sometimes inconsistent regulatory climate, greater synergy between regulations would be beneficial for the overall planning and implementation of AM (LoSchiavo, 2010).

Reviews of the program from the public have been mixed. In 2008, Senators John McCain and Claire McCaskill acknowledge the need for restoration but also opposed federal funding for the Everglades without greater transparency in the planning and use of funding (Sheppard, 2008). A 2010 editorial by Charles Lee and Tom Feeney argued that whether or not implementation of the program was more appropriate than curtailment of water for agricultural needs (Lee, 2010).

COST-BENEFIT ANALYSES

The program complied with the requirements of the Civil Works process by establishing a range of operational performance goals for individual projects. These ranges established the basis for cost estimates (including operational costs), cost-benefit analyses, and development of compliance documents (LoSchiavo, 2010). The typical process also involved incremental cost benefit analyses (benefits provided by a new project or increment of the program). The process begins when a tentative project was identified that met the project purpose and need,. The individual project was then analyzed assuming it represented a Next-Added Increment (NAI) of the overall program (U.S. Army Corps of Engineers, Jacksonville District, and South Florida Water Management District, 2010). The NAI analysis evaluated the benefits (including national outputs, such as restoration) of the Tentatively Selected Plan as the next project that would be developed as already approved CERP projects.

> *This analysis helps illuminate the amount of benefits the tentatively selected plan contributes without regard to future CERP projects. It also helps to ascertain whether sufficient benefits will accrue to justify the cost of the project if no additional CERP projects (other than those already existing or authorized) were implemented.*
> (U.S. Army Corps of Engineers, Jacksonville District, and South Florida Water Management District, 2010)

Another unique aspect of the storm water treatment areas implementation involved specific federal policies for funding. Federal cost-sharing of individual water quality features not specified in the CERP requires individual funding on a project-by-project basis using cost-benefit analysis (Committee on Independent Scientific Review of Everglades Restoration Progress, National Research Council, 2010).

Analysis of the Literature and Case Studies

EMERGING IMPROVED UNDERSTANDING OF AM

The National Research Council's working definition of the AM focuses upon many of the major premise and goals of AM but does not illustrate the major components or elements of and planning considerations for AM implementation, particularly for a large and complex ecosystems.

> *Adaptive Management (is a decision process that) promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events became better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process. Adaptive management also recognizes the importance of natural variability in contributing to ecological resilience and productivity. It is not a 'trial and error' process, but rather a means to more effective decisions and enhanced benefits. Its true measure is in how well it helps meet environmental, social, and economic goals, increases scientific knowledge, and reduces tensions among stakeholders.*
>
> (U.S. Department of Interior Adaptive Management Working Group, 2009)

Each AM program can have unique attributes. The level and type of uncertainties; potential losses resulting from either delaying or failing at AM for ecologically and commercially-significant resources; regulatory requirements; political climate; and the ecosystem can vary dramatically. A fundamental aspect of all AM is that the other more conventional approaches utilizing historical data are not sufficient to address the program's needs. The case studies combined with the literature suggest several AM attributes that are critical to success of a program:

- Chartering of involved agencies
- Integrated governance by decision-makers, scientists, engineers, and other professionals with independent peer review
- Technological and procedural methods for data collection, storage, and analyses
- Feedback mechanisms to incorporate monitoring and performance as well as public involvement into future implementation
- Effective program management, including cost-benefit analyses, periodic third-party programmatic assessments, and performance measures

The following sections compare and contrast the two case studies in terms of (1) planning, implementation, and results and (2) cost-benefit approaches to address uncertainty.

PLANNING, IMPLEMENTATION, AND RESULTS

Both the Bay Delta effort and the Everglades programs are funded and managed in large part by the USACE, UFSWS, and a major state agency. Each of the programs was and is required to comply with similar regulations (NEPA and the ESA among others) as well as program requirements under the USACE Civil Works process. To comply with these requirements, both programs relied upon programmatic EIS's, BOs, and project-specific NEPA documents. These work approaches included programmatic alternatives analyses based upon baseline studies and conceptual models followed by project-specific alternatives analyses for individual projects. Improved understanding of the system and thereby AM was achieved through implementation (or compliance) monitoring and effectiveness monitoring with targeted studies. As a result, feedback mechanisms typically focused upon refining future projects rather than evaluating multiple hypotheses concurrently. Therefore, the approach to AM for both programs was essentially passive in nature.

The Everglades' project is much more mature than the Bay Delta initiatives and appears to be within the Gunderson et al's policy alternative generation or renewal phase; although it appears that the Bay Delta initiatives are just entering this phase. As a result, the Everglades program has a substantial advantage in the resolution of common issues affecting AM.

Both projects have experienced program challenges related to common issues of AM:

- Effectively managing various forms of uncertainty (which is described in greater detail in the following section)
- Clearly communicating goals based upon science
- Effectively engaging dedicated decision-makers with clear leadership
- Obtaining adequate funding for monitoring programs
- Avoiding the "Management Trap"
- Establishing realistic cost-benefit analysis protocols (which is described more in the following section)

The differences between the successes and failures of the two programs are instructive. Both have relied upon conceptual and numerical models to predict system performance with success. Exceptions include the predicting the success of restoration efforts for specific species within the Bay-Delta and water quality in the Everglades. The initial success of CALFED from a CAN perspective was well-recognized, but is now under redevelopment. The Everglades' current program of extensive interaction between stakeholders and participants combined with formal decision-making is considered to be generally effective; however, critics of the program encouraged more proactive and timely implementation. Defining the program mission and harnessing the benefits of public involvement without falling prey to ambiguity remains a concern for both projects.

Both organizations have benefited from dedicated and committed leaders but experienced severe criticism by outside parties. Much of the criticism focused upon negative perceptions of financial effectiveness, financial transparency, and the speed of restoration success. Funding has also been either at risk or limited at different phases of both programs. Due to the phased approach to implementation and monitoring, the risk of inadequate or ceased funding remains a concern for both programs. This is especially associated with the Civil Works phased funding approach.

It also appears that both parties have experienced some negative aspects of the "management trap" with the issues involving inter-institutional or regulatory issues. This included the criticism which CALFED experienced regarding its effectiveness and performance goals and the delays due to political wrangling and criticism experienced by the Everglades during the 1990's.

Uncertainty And Cost-Benefit Analyses Of The Two Studies

Both programs relied upon conceptual modeling to understand ecological uncertainties. These understandings and remaining uncertainties were typically addressed by establishing a potential operational range for specific projects, such as environmental flows. The Everglades work approaches, which rely heavily upon systematic and formal mechanisms of identifying and resolving uncertainty while also establishing accountability from a financial and performance perspective, appear to be the most successful. This is due in large part to the program's maturity, consistent funding, and previous experiences. This includes the introduction of the NAI and biennial evaluations of performance by an outside party. The Everglades program experience suggests that incorporation of uncertainty in benefit-cost analyses must be carefully combined with performance measurements and program management.

A key consideration of the incorporation of cost-benefit analyses in future AM projects utilizing federal funding, especially Civil Works projects, involves its expression of uncertainty. In the Everglades, the potential benefits of the project are compared to the potential costs for various alternatives in accordance with Civil Work guidance (LoSchiavo, 2010). A range of outcomes has been used to satisfy the need to define objectives, estimate costs, but also provide flexibility to meet the larger goals of the restoration effort (LoSchiavo, 2010). However, the current guidance framework does penalize programs that elect to conservatively estimate monitoring and other AM costs in favor of programs that do not consider or less conservatively such costs. The current guidance for Civil Works does not readily lend itself to an active AM approach, even in the early phases of a project.

CHAPTER 5 CONCLUSIONS

The implementation of AM for large-scale, regional restoration efforts continues to be a challenging but promising approach for management of regional water resources particularly in the face of competing ecologically and commercial interests of national significance. The following sections summarize criteria for consideration of new AM programs and potential improvements for the practice of AM, particularly in the United States.

Criteria for Consideration of AM

Future guidance on the use of AM should incorporate specific criteria for the consideration of AM. These include the following:

- The likelihood that AM can improve understanding or implementation beyond historical data and traditional planning methods
- The ability of ecological and political systems to both absorb and foster change (resiliency)
- Consensus regarding the science and objectives of the effort which reduces ambiguity and refines working tools
- Ability to fund short and long-term aspects of the program to ensure AM is viable
- Feasibility and benefits of combining passive and active AM into a given program at different phases

Improving the Practice of AM in the United States

Literature and case studies suggest that several features are necessary to successfully implement AM and leverage the best science and results. These components are summarized as follows (Table 4) and further described in the following sections.

Component	Description
Adaptive Governance and Complex Adaptive Networks	A strong governance structure coupled with independent peer review; committed, educated leaders; financial and performance programs, and data collection are essential. Data must be communicated quickly, efficiently, and in a usable form for decision makers.
Funding Availability	Short and long-term funding is necessary for all phases of the effort including monitoring and data management.
Provisions for Active AM	Failure to establish provisions for active adaptive management in the early phase of restoration effort may prevent learning and potential later acceleration of the AM approach.
Cost-Benefit Analyses	Accurate and frequent reassessment of cost-benefit analyses is a key to effective program management and financial transparency. When evaluating multiple projects, cost-benefit analysis techniques should not incorporate a bias towards implementation (passive AM) and against experimentation (active AM) because this approach discounts learning.
Delegation of authority	Policies to allow parties to implement AM with increased authority to vary operations to achieve their goals should be sufficient to allow more efficient and timely implementation without making entities vulnerable to the "management trap."

Table 4. Summary of Key Features

ADAPTIVE GOVERNANCE AND COMPLEX ADAPTIVE NETWORKS

The concept of adaptive governance was first established by Gunderson and Light in relationship to the Everglades (Gunderson & Light, 2006). They argue that CANs or appropriate systems for integration of science, technology, and decision-making are critical for the success of AM. Effective adaptive governance, including institutional and individual decision-makers' commitment to the project, are critical. Research also suggests that effective adaptive governance requires consistent and complementary terminology, regulatory objectives, and evaluation criteria. This logic suggests that the future of AM within the United States would benefit from the adoption of consistent guidance for evaluating technologies, managing and visualizing data, and identifying and interpreting uncertainty amongst key agencies involved on the national level. This approach must coincide with rigorous training and chartering for local and state agencies engaging in adaptive governance.

COMMITMENTS TO FUNDING

Short and long-term funding is critical to establish and later implement and monitor AM. The traditionally passive approach to AM in the U.S. combined with phased funding and potential changes in political and stakeholders objectives make large-scale restoration efforts particularly vulnerable. This is particularly true when a program advances through the PED, construction, and operational phases of a Civil Works process. Many of the current funding methods do not incorporate mechanisms to evaluate and fund active AM which can result in delayed learning.

PROVISIONS OF ACTIVE ADAPTIVE MANAGEMENT

The learning generated by active AM may be valuable in the early stages of a restoration effort. In both the current phase of the Bay-Delta and Everglades, particularly the CERP, both programs benefited from prior learning in earlier project phases where hypotheses were evaluated by individual, more passive work approaches. In both instances, these earlier phases mimicked the components of an active AM. Following these phases, both programs experienced decline and reemergence following this phase.

As a result, this situation suggests that an evaluation of active AM in the early phases of major projects might be beneficial and cost effective. This effort might be most valuable in the reconnaissance phases of projects funding by the USACE (which precede the feasibility phase) as well as a complementary effort during general baseline documentation and initial trend analyses. The results of hypotheses can then be used to improve the effectiveness of future phases of the program. This data could also be used to inform the range of costs and benefits during the reconnaissance phase for consideration prior to the feasibility phase.

COST-BENEFIT ANALYSES

Another key consideration in AM is the careful application of cost-benefit analyses and incremental cost-benefit analyses techniques. This approach can be particularly critical when funding is limited and results are urgently needed to protect a non-renewable, threatened resource. It can also aid in establishing and maintaining financial transparency and evaluating performance. Opportunity costs as well as intergenerational benefits are also valuable metrics to support complex decision-making. Consistent protocols nationally for cost-benefit analyses of water resources projects that allow accurate and unbiased consideration of active AM would aid decision-making and also better focus national funding for major restoration programs.

DELEGATION OF AUTHORITY FOR FLEXIBILITY IN IMPLEMENTATION

A successful AM framework must include the delegation of authority to implement projects in a flexible, but accountable manner. By delegating authority, guaranteeing funding with acceptable performance, and implementing the other approaches identified in this section, institutions implementing ecosystem restoration would be better insulated from the "management trap."

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